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THESIS

COST ANALYSIS OF NAVY ACQUISITION ALTERNATIVES FOR THE NAVSTAR GLOBAL POSITIONING SYSTEM

by

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December 1982

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Cost Analysis of Navy Acquisition Alternatives for the NAVSTAR Global Positioning System

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ABSTRACT

This research analyzes the life cycle cost (LCC) of the Navy's current and two hypothetical procurement alternatives for NAVSTAR Global Positioning System (GPS) user equipment. Costs are derived by the ARINC Research Corporation ACBEN cost estimating system. Data presentation is in a comparative format describing individual alternative LCC and differential costs between alternatives. Sensitivity analysis explores the impact receiver-processor unit (RPU) first unit production cost has on individual alternative LCC, as well as cost differentials between each alternative. Several benefits are discussed that might provide sufficient cost savings and/or system effectiveness improvements to warrant a procurement strategy other than the existing proposal.

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I. INTRODUCTION

This analysis describes the results of an examination of the Navy's procurement strategy for the NAVSTAR Global Positioning System's (GPS) user equipment. The research was undertaken in response to a study request presented by the Navy Program Director of the Joint Program Office.

Current Navy User Segment cost estimates to procure and maintain the installations in the approximately 5,350 Navy/Marine Corps vehicles identified to receive the system approach one billion fiscal year (FY) 1979 dollars. Because of this large investment, it is requisite that the most cost effective procurement strategy of user equipment (UE) be pursued to minimize both the investment and support costs over the system's expected life.

A. BACKGROUND

The Global Positioning System is a space-based navigation system currently in Phase II (full scale development) of a three phase acquisition process. The Defense Systems Acquisition Review Council (DSARC) final production decision is planned for the latter half of fiscal year 1984. The acquisition is a tri-service, joint program with the Air Force assigned as the executive service. All military branches, the Coast Guard, and the North Atlantic Treaty

Organization (NATO) are represented in the program structure. Current estimates of the system's total cost to Department of Defense (DOD) users exceeds 8.5 billion FY 1979 dollars for an estimated 27,000 eventual U. S. government units.

The system is composed of three segments. These are: (1) Space Segment--consisting of a proposed constellation of eighteen navigation satellites; (2) the Control Segment--consisting of satellite control stations, radar sites, and other ground support functions; and (3) the User Segment--consisting of the actual navigation receiver-processor electronics and display units to acquire navigation data from the satellites and to display it in usable form in the various host vehicles.

From a costing standpoint the Air Force bears the costs of the satellites and control segments, while research, development, test and evaluation (RDT&E) costs will either be jointly shared or borne by individual services. The investment costs of the user equipment (UE), along with the retrofit/installation costs, and the operational and suppc. (O&S) costs will be borne by each individual service acquiring the system.

Life cycle costs (LCC) are planned to be minimized through insistence on Design-to-Cost concepts and modular construction of both hardware and software with an effort towards maximum commonality and interoperability of user

equipment among the numerous host vehicles. Host vehicle dynamics, design and cost constraints, have resulted in three categories of user equipment. The three categories are: (1) a low dynamics (one-channel) receiver for slow-moving land-based personnel or vehicles; (2) a medium dynamic (two-channel) receiver for ships, helicopters and slower moving transport/patrol aircraft; and (3) a high dynamic (five-channel) receiver for tactical aircraft and special submarine applications.

B. OBJECTIVES

This research presents and compares life cycle costs for the Navy's current acquisition strategy and the costs associated with two alternative procurement strategies. Benefits for each alternative will be presented with emphasis given to the incremental enhancements possibly available from the alternative solutions.

Although this study examines procurement strategies as well as resultant system costs, it does not attempt to answer the basic question, "Are expenditures for procurement and operation of GPS justified by the improved military capabilities the system can provide?" The answer to that question must result from a decision maker's judgment assessing relative military value of the system, available funding and alternative ways in which such funds might be used. Those considerations are beyond the scope of this

study. However, an attempt is made to provide a decision maker with an analysis of procurement alternatives once the "buy" decision has been made.

C. METHODOLOGY

The method of analysis is to compare cost estimates for the existing Navy UE platform integration concept with two alternatives proposed by the researchers. In essence, these proposals vary the baseline concept with respect to the types of receiver-processor units to be installed onboard Navy/Marine Corps platforms.

The current UE proposal (Case I), to be examined and used as the baseline for comparison, calls for a specific mix of medium and high dynamic receiver-processor units (RPU's) on aircraft and ships. This mix is based predominantly on host vehicle dynamic requirements.

The first alternative (Case II) provides all Navy aircraft with a high dynamic RPU. This alternative would disregard the lower dynamic requirements of helicopters and patrol/transport aircraft in favor of high dynamic commonality for aviation assets. The ships that were assigned the medium dynamic RPU in Case I are not changed.

The second alternative (Case III) provides the high dynamic RPU to all Navy aircraft and ships. Thus all Navy sets are of the high dynamic configuration.

For these alternatives, cost estimates are derived for procurement and installation of the GPS set hardware and Operating and Support costs using the Automated Cost and Budget Estimating Network (ACBEN) system developed by ARINC Research Corporation in support of the NAVSTAR GPS program effort. These cost estimates are presented in constant FY 1979 dollars which are in consonance with existing directives concerning budgetary submission of GPS cost requirements.

Using the current procurement strategy as the baseline, a comparative cost analysis of the defined procurement strategies was prepared.

D. THESIS ORGANIZATION

Chapter II presents a brief summary of significant developments in space navigation programs and discusses the inception and growth of the NAVSTAR Global Positioning System. Chapter III describes life cycle costing in acquisition management. Since LCC comparisons are the basis upon which both the analysis and conclusions of this study are based, it is important to the reader's understanding and assimilation of our discussion that he first comprehend the basic tenents of the LCC concept. Chapter IV reviews the cost estimating models that are used in the analysis for determining the LCC of Navy GPS UE. Chapters V, VI, and VII contain the analysis of the thesis. Chapter V identifies the cost differentials among the three possible strategies and

presents them in a comparative format for the sensitivity and benefit analyses which are presented in Chapters VI and VII. Finally Chapter VIII summarizes the findings and briefly recommends an acquisition alternative for Phase III UE selection.

II. BACKGROUND AND SYSTEM DESCRIPTION OF THE GLOBAL POSITIONING SYSTEM

A. BACKGROUND AND HISTORY

In this chapter we provide a brief summary of significant developments in space navigation programs and discuss the inception and growth of the NAVSTAR GPS.

Since the early 1960's the Navy and Air Force have actively pursued the concept of navigation using radio signals transmitted from space vehicles whose positions in space are accurately known. The impetus for such a space-based navigation system was the broad spectrum of military and civilian users to whom precise, global navigation is desirable, as well as the cost benefits which would result from reversing the trend toward proliferation of specialized navigation equipment. The Navy sponsored two such systems: TIMATION, and TRANSIT (which is presently operational). The Air Force concurrently embarked on the design of a highly accurate, three-dimensional system called 621B.

On 17 April 1973, the Deputy Secretary of Defense issued a memorandum which designated the Air Force the executive service in an effort to develop a joint service navigation system which would build on the technological achievements of the predecessor Air Force and Navy programs, and also incorporate the position/navigation requirements of the Army and the Defense Mapping Agency. Thus the NAVSTAR Global

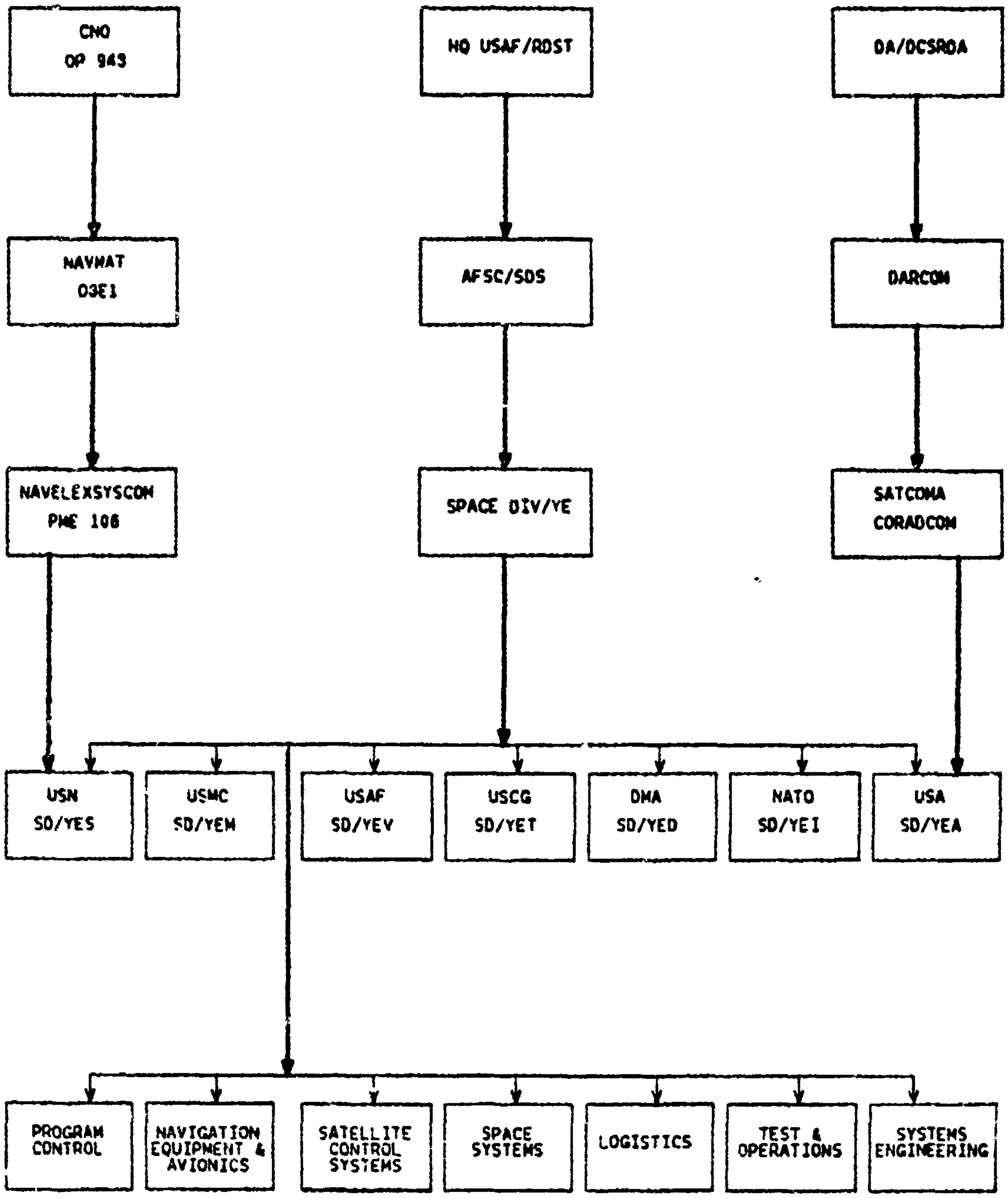
Positioning System (GPS) was inititated. NAVSTAR GPS was briefed to the Defense Systems Acquisition review Council (DSARC) on 13 December 1973, and was approved by the Deputy Secretary of Defense on 22 December 1973 [Ref. 1].

The NAVSTAR Joint Program Office (JPO) is located at the Air Force Space and Missile Systems Organization (SAMSO) in El Segundo, Califnoria. In addition to the Air Force Program Manager the JPO includes Deputy Program Managers representing the Army, Navy, Marine Corps, Coast Guard, Defense Mapping Agency, and NATO. Figure 2.1 depicts the organizational structure of the Joint Program Office.

Superimposed on this program management organization is a supporting matrix organization comprising contract management teams, one for each major development/acquisition contract associated with the three program segments.

B. NAVSTAR SYSTEM DESCRIPTION

The Global Positioning System is a space-based navigation system that is designed to provide highly accurate three-dimensional position (to within 16 meters spherical error of probability (SEP)), velocity (to within 0.05 meters/second) and system time (to within 55 nanoseconds) to suitably-equipped users on or within 500 miles of the earth. The GPS consists of three major segments: Space Segment (satellites), Control Segment (satellite tracking and control), and User Segment (navigation receiver sets)[Ref. 2].



Source: Joint Program Office

Figure 2.1 Organizational Structure Chart

1. Space Segment

The operational GPS Space System Segment includes three planes of satellites in circular 10,898 nautical mile orbits, with an inclination of 63 degrees and a 12 hour period. Each plane will contain six satellites. This deployment will provide adequate satellite coverage for continuous and world-wide three-dimensional positioning, navigation and velocity determination. Each satellite transmits a composite signal at two L-band frequencies consisting of a precision navigational signal and a coarse acquisition (C/A) navigational signal. The navigational signals contain satellite ephemerides (satellite positions), atmospheric propagation correction data, and satellite clock bias information provided by the Master Control Station. In addition the second L-band navigation signal permits the user to determine the group delay due to the ionosphere or other electromagnetic disturbances in the atmosphere [Ref. 3].

2. Control Segment

The operational control segment will consist of a Master Control Station (MCS), Ground Control Station (GCS), Monitor Stations (MS), and an alternate Control Center (ALT). The MCS and GCS are together referred to as the NAVSTAR Control Center (NCC). Initially the NCC will be located at Vandenberg Air Force Base. The number and location of MS's are to be determined. The MS's collect satellite tracking

data from all satellites in view. This data is combined with environmental data, encrypted and transmitted to the NCC and/or ALT. The NCC and/or ALT use the data to generate new space vehicle ephemerides and clock offset updates and transmit these updates to the space constellation. In addition, the NCC and/or ALT will perform satellite maintenance and housekeeping functions [Ref. 4].

3. User Segment

The NAVSTAR User Equipment (UE) set consists of a receiver and navigation processor. For the most demanding case, that of a high dynamic host vehicle, the user set requires signals from four satellites to continuously solve for the user's three dimensional position and time. The position solution is computed in World Geodetic Survey--WGS 72 coordinates, and can be instantly converted to a large number of other reference systems or units. In high dynamic vehicles, the GPS user equipment is usually tied to an Inertial Measurement Unit (IMU) to maintain navigation accuracy during high acceleration maneuvers. This equipment configuration is referred to as the Aided User Set [Ref. 5].

The application of GPS user equipment in various types of host vehicles, utilized under a wide variety of operational conditions, has led to the development of three types of receiver-processor units--the Low Dynamic (one-channel), Medium Dynamic (two-channel), and High Dynamic

(five-channel) units. The five-channel set continuously tracks and monitors four satellites simultaneously. The fifth channel is used to improve user set performance. The design assumption is that the five-channel set will normally be used in a vehicle operating in a highly dynamic and/or high-jamming environment, or in a vehicle where fast acquisition of GPS signals is required.

Where operational conditions such as vehicle dynamics, operating time constraints, and jamming levels are less stringent, the one or two-channel sets may be used. The single-channel set tracks and monitors four satellites sequentially. In the two-channel set, the channels sequentially track and monitor two satellites each.

The sequential GPS sets must "time share" the receiver-processor electronics. For example, in the two-channel sequential set the satellite ranging data is gathered from two satellites, then two other satellites are acquired, and their ranging information is computed. The delay involved maybe only a few seconds in time (usually 1-2 seconds) yet can vary considerably in actual position, depending on platform type and velocity.

From a performance comparison standpoint all three receiver-processor variations, (i.e., high dynamic, medium dynamic, and low dynamic RPU's), if placed in close proximity with no jamming present and stationary in position, will

provide identical position, velocity, and time information. Accuracy is enhanced if the user is stationary. However, once the user set is placed in motion the position, velocity and time agreement among the sets will begin to deteriorate. When the platform velocity exceeds approximately fifty knots, the one-channel RPU will be unable to "track" its own movement. The receiver cannot sequentially select the four necessary satellites quickly enough to solve a navigation problem. The two-channel set will be overcome by dynamics at approximately 775 knots. The total combination of all platform dynamic movements (i.e., velocity, acceleration, jerk, yaw, pitch, and roll) significantly reduces the performance thresholds for the two mentioned RPU's. Within this operating constraint, only the five-channel RPU can satisfactorily solve the equation for navigation information.

It should be recognized that certain variations in UE set design and interface will be required to adapt a set type to a particular host vehicle. This adaption is usually accomplished by utilizing different interface modules or by substituting like items from other set types. The heart of each set, the receiver-processor unit, is the same for all installations of that set type. That is, a medium dynamic (MD) RPU in an Air Force transport aircraft is identical to the RPU on a naval aircraft carrier or an Army helicopter. A description of the set's system elements (antenna,

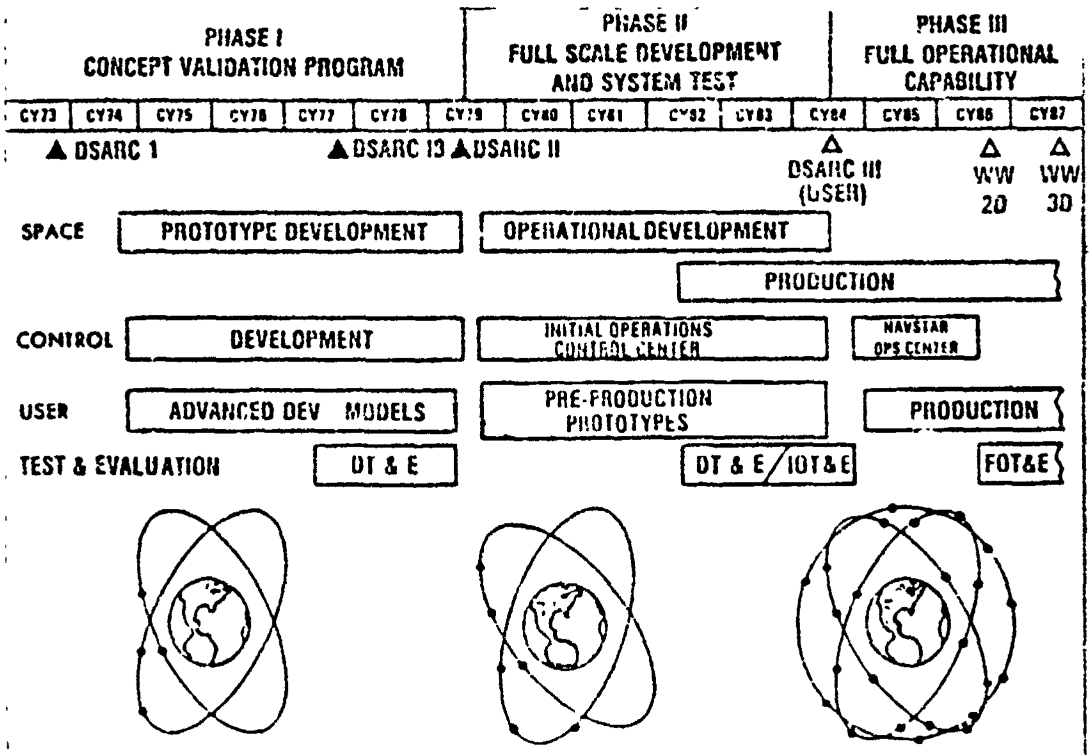
receiver-processor unit, control and display unit, etc.) and interrelationships of these system elements is presented in a later section.

C. ACQUISITION APPROACH

The acquisition approach for the GPS recommended by the DSARC was a step-wise, design-to-cost development and test program leading in successive phases to an operational Global Positioning System. Each phase is designed to build and expand on the previous phase in an integrated and cohesive manner as may be seen in Figure 2.2. The decision at DSARC I (held in December 1973) was to proceed with Phase I, Concept Validation, which concentrated on validation of design concepts through Development Test and Evaluation (DT&E) of user equipment. Follow-on efforts in Phase II, Full Scale Development, will complete the DT&E and Initial Operational Test and Evaluation (IOT&E) of user equipment. Finally during Phase III, Production/Deployment, full GPS capability should be achieved[Ref. 6].

1. Phase I

During Phase I, development of the space segment included six Navigation Development Satellites (NDS). This constellation provided a four-in-view geometry similar to the global system, permitted equipment testing for a period of up to four hours per day over selected test areas, and provided the satellite coverage required to support the Navy's Fleet



Source: NAVSTAR GPS User's Overview

Figure 2.2 NAVSTAR Program Evolution

Ballistic Missile (FBM) Improved Accuracy Program (IAP). In order to continue to support the Navy's IAP through the early 1980's, replenishment satellites are being procured and will be launched as required.

The control station, used for tracking of the satellites, was developed and tested as a prototype of an operational control station. The space and control segments together provided a test environment for the DT&E and limited IOT&E of user equipment which is representative of the operational system.

Phase I was the first of two design-build-test-design cycles to determine preferred user equipment configurations and validate life cycle cost models in the design-to-cost process. The purpose of this approach was to reduce overall program risk, to reduce projected user equipment design costs and life cycle costs through encouraging innovative designs, to increase industry competition by broadening the industrial base, and to fully investigate the potential classes of user equipment.

During this phase three generalized development models were built and evaluated. They were the X-Set (high dynamic prototype), Y-Set (developed for applications where dynamics allow sequencing of a single receiving channel over four selected satellites), and the Z-Set (developed where performance was deliberately compromised to achieve a minimum

cost to the user). Over 600 test missions were performed using these sets, culminating in concept validation for the GPS system.

Four parallel study contracts were let near the end of Phase I to define the user set classes for Phase II IOT&E. Emphasis was placed early in these contracts on low development costs through the use of modular hardware and software designs, while total life cycle costs were minimized through the use of common modules across various host vehicle categories, wherever possible. The four twelve-month studies culminated in proposals for the development of UE IOT&E prototypes in Phase II. Based on these designs, two of the four contractors, Magnavox and Collins, were selected to proceed with Phase II [Ref. 7].

2. <u>Phase II</u>

Phase II includes: (1) continued design, development and test of Phase I developed satellites; (2) continued use of Vandenberg Air Force Base as the NCC; (3) the design, fabrication and testing of prototype UE for technical and operational evaluation onboard Navy and other services' platforms; and (4) production of replenishment satellites to maintain a minimum constellation of four space vehicles for IOT&E through fiscal year 1983.

The user equipment activities in Phase II are primarily concerned with developing and testing the

prototypes of user equipment. The two contractors are developing the basic architecture for a family of user hardware to be used in all designated hosts. This approach may provide commonality across all classes of user equipment designed by each contractor and should achieve the anticipated cost benefits in Phase III [Ref. 8].

3. Phase III

The decision for full production will be made at Milestone III scheduled for the latter part of 1984. Phase III features (1) deployment of the full satellite constellation; (2) upgrading and operation of a backup MCS and upload station (ULS); and (3) production/deployment of all classes of user equipment.

The user equipment will be procured in large lot buys. The initial Phase III contractor will be selected from the competing Phase II contractors. A leader/follower(s) procurement concept is envisioned for the production of the preferred Phase II design with the leader qualifying a second production source(s) after the first production contract award. Follow-on Test and Evaluation (FOT&E) will be completed prior to installation of user equipment.

In summary the three-phased development and deployment of the NAVSTAR GPS is an evolutionary process. Each step provides extensive legacy value for the next step [Ref. 9].

III. LIFE CYCLE COSTING IN ACQUISITION MANAGEMENT

This study will present cost comparisons of alternative procurement strategies for the Global Positioning System's User Segment. To do so, the economic analysis technique of Life Cycle Costing (LCC) will be employed. This technique was chosen for the analysis of GPS costs because it reduces the different elements comprising alternative acquisitions to a common basis for measurement and comparison--dollars. Although many persons familiar with acquisition/program management will have seen or utilized the technique themselves, others reviewing this study may be only superficially aware of LCC's benefits and weaknesses as an analytical tool. Since life cycle cost comparisons are the "bed rock" upon which both the analysis and conclusions of this study are based, it is important to the reader's understanding and assimilation of our discussion that he first understand the basic tenets of the LCC concept.

The intent is not to make an LCC analyst of the reader. Rather, it is to provide a common point of departure for those persons reviewing this analysis. The objective is to provide "sufficient" discussion concerning LCC to familiarize, or in some cases to refamiliarize, the reader with this technique.

In so doing, a review of life cycle cost's origin is provided. Pertinent concepts and definitions are discussed. Second, an overview of the objectives of LCC as an estimating technique will be presented. Then a more extensive discussion of LCC methodology will be undertaken to provide the reader with the knowledge requisite for understanding an LCC model which is detailed in Chapter IV.

For those persons with significant experience with life cycle cost techniques, this chapter may be either skimmed or skipped entirely without loss of analytical continuity. Those persons desiring a more detailed discussion of the military applications of LCC should refer to some of the numerous references available. They are found partly in the form of DOD and service-level directives and instructions. In addition, many life cycle cost analysis "user guides" and handbooks are provided by various DOD and service commands involved with either cost estimation or estimate validation for acquisition programs.

A. DEFNIITIONS, CONCEPTS AND HISTORY OF LCC

To provide a consistent foundation upon which to build our discussion, this section will provide definitions to pertinent cost-related terms. In addition a short discussion of the evolution of "cost" and particularly life cycle cost as a program management tool will be presented.

1. Definitions

The following definitions will be utilized through the remainder of this research. They are important to a basic understanding of the purpose and use of cost estimation as a management technique [Ref. 10].

a. Life Cycle Cost (LCC)

LCC is the sum total of cost either estimated or incurred, from the development, investment, operation and support and disposal of an equipment or weapon system over its useful life.

b. Development Cost

Develpment cost is the sum of all contract and in-house costs necessary to bring an acquisition from the conceptual phase to production.

c. Investment Cost

Investment (procurement) cost is the sum of all costs required to transform the results of development into a fully operational system or equipment.

d. Acquisition

Acquisition cost is the sum of development and investment costs.

e. Operating and Support (O&S) Cost

O&S cost is the sum of all costs required to operate, maintain, supply and support an acquisition.

f. Life Cycle Cost Analysis

LCC Analysis involves the identification, quantification, and qualification of LCC by segmenting aggregate program costs with the intent of clarifying cost interrelationships and determining the effect of each cost contributor to the system's total LCC.

g. Cost Element

A cost element is the lowest level of identified cost for a given LCC analysis. A cost element is further broken down into rates, factors and constants related mathematically which produce a dollar figure corresponding to an aspect of the system or the equipment under investigation.

h. Cost Element Structure

A cost element structure is a set of cost elements arranged in a heirarchy according to the LCC objectives. The cost element structure may be different in each phase of the life cycle.

i. Cost Category

A cost category is a set of cost elements aggregated by a particular rule or definition. MIL-STD-881 provides the basis for comparison of all LCC analyses within the perview of the Department of Defense.

2. History of LCC Techniques

LCC has evolved over the last twenty years to become a potentially important managerial tool in the defense

acquisition process. Its basis is founded in DOD policies, directives and in the Defense Acquisition Regulations (DAR Section 1-35) which states:

> Since the cost of operating and supporting the system or equipment for its useful life is substantial and, in many cases greater than the acquisition cost, it is essential that such costs be considered in development and acquisition decisions in order that proper consideration can be given to those systems or equipments that will result in the lowest life cycle cost to the government.

Although LCC consideration is mandated by this regulation, it should be noted that the technique is seldom used to its full potential as a program management tool.

a. Cost as a System Evaluation Criterion

During the mid-1960's the rapidly increasing technical complexity of defense acquisitions led to steadily rising unit procurement costs. These increases in costs along with a general economic inflationary trend resulted in vigorous efforts to constrain the cost growth then associated with military systems' acquisition.

The increased emphasis on cost during the 1960's led to techniques which included "cost" as a major system evaluation criterion. Prior to this time the two criteria predominantly used for defense systems evaluation and selection were "performance" and "schedule." These criteria were used to evaluate a system on its ability to combat a foreseen threat (performance) and whether it could be

developed and deployed in a time period considered reasonable to meet that threat (schedule).

b. McNamara's Cost-Effectivness Analysis

The initial concepts developed during the 1960's to control military acquisition cost grew from Secretary of Defense McNamara's systems analysis efforts. The first control technique which ensued was that of cost-effectiveness analysis. Cost-effectiveness analysis techniques were utilized to systematically quantify both the costs and benefits of decision alternatives. Studies were termed "cost-benefit" if the identifiable benefits could be measured in dollar values. Alternatively, those analyses which could not reduce benefits to quantifiable dollar values became known as "cost-effectiveness" analyses.

c. Evolution of Life Cycle Cost Analysis

The second technique which evolved from the increased interest in cost control was life cycle cost analysis. This technique was devised and utilized to more adequately define not only the cost of a system's acquisition, but to identify the future costs associated with its operation and support. The identification of these costs was of particular importance when it was considered that in many weapons systems the "ownership" costs over the life cycle far exceeded the initial acquisition costs of the system itself.

d. DTC/DTUPC

Two other techniques have since evolved. The first, Design-to-Unit Production Cost (DTUPC) emphasizes the importance of designing systems in a manner which minimizes their unit production cost. The shortcoming of this technique is that its focus is on control of acquisition costs, perhaps without regard to the future costs of ownership of the weapons system.

The second technique, Design-to-Life-Cycle-Cost (DTLCC), commonly known as Design-to-Cost (DTC), was developed in acknowledgement of the importance of ownership costs and the impact that design decisions played on these future costs. The common basis in both these techniques is that trade-offs in performance and schedule are utilized in an attempt to meet cost goals which are set early in a system's development.

Only LCC analyses provide for estimation and control of all three phases of a system's cost--development, investment, and operations and support. Utilization of LCC techniques in an acquisition can help avoid suboptimal emphasis on production costs at the expense of future operating costs. However, implementation of the techniques has been slow and the use of LCC as a design parameter has met with varying degrees of success [Ref. 11].

B. OBJECTIVES AND APPLICATIONS OF LCC

DOD Directive 5000.1 requires all military departments to pursue the most cost effective balance between the acquisition and ownership costs of a new weapons system. DOD Directive 5000.2 addresses the need to consider system "affordability" at each milestone in the acquisition process. The concept of affordability requires that the decision to procure a weapon system, no matter how desirable, be dependent upon the government's ability to fund not only its development and acquisition, but also its operation.

Application of LCC techniques can assist the Program Manager (PM) in the implementation of these policies in his office. This section will discuss the specific objectives and underlying purposes of LCC and the means through which these goals are fulfilled.

1. Objective of LCC

The objective of LCC analysis is to provide quantified, qualified and time-phased cost information to decision makers for assistance in resource allocation planning and management.

The more specific purposes of analyzing cost information are [Ref. 12]:

- To estimate the total cost to the government emphasizing yearly obligations required by the acquisition.
- Reduce the total cost through LCC trade-offs in the design, operation, maintenance and support development processes.

- Control costs through use of LCC provisions in acquisition contracts.
- As a managerial decision-aid in the determination of whether to proceed to subsequent acquisition phases.

It is evident from these stated purposes that LCC techniques have direct applications for cost estimation and control. Both these applications support resource allocation and expenditure decisions.

2. Applications of LCC Analysis

Life cycle cost analyses are appropriate for a number of managerial applications dealing with resource consumption. For example, LCC analysis may be applied not only to specific system acquisition decisions but also to internal program decisions concerning system design, support and others.

LCC analyses are generally applied to two broad uses: (1) as a cost estimation technique to support managerial decisions and (2) a cost control device. While both applications attempt to provide accurate, time-phased estimates of life cycle costs, each emphasizes slightly different cost issues. This section will address only the application of LCC as a cost estimation technique for decision support.

a. LCC as a Decision Support

In their use as a decision support, LCC analyses are generally directed toward a comparison of either

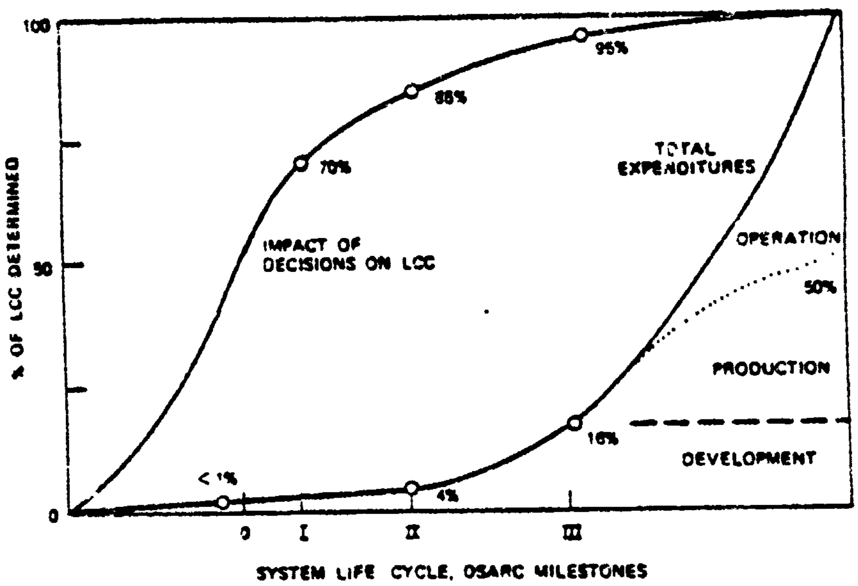
engineering-oriented or more broad acquisition management problems.

Typically the uses of engineering-oriented LCC analyses are to answer questions internal to the program office. In particular questions concerning LCC differentials resulting from performance, schedule, and cost trade offs are addressed. These analyses are especially helpful during the design stages. Here they seek to quantify the production and O&S costs which might result from the selection of a particular design alternative.

Figure 3.1 indicates that system design decisions have a direct and major impact on future O&S costs [Ref. 13]. It is estimated that by the commencement of Phase II of an acquisition (Full Scale Development), 75 per cent of the LCC-influencing decisions have been made. Consequently, there is a need for major emphasis on LCC estimation early in the design phase to support these decisions which impact ownership costs.

The second use of life cycle cost analyses as a decision support is much broader and deals more directly with macro-level, managerial instead of engineering decisions.

In this case LCC estimates can be structured to support program decisions such as the proper quantity and "mix" of a particular system. This is the use of life cycle costing which will be utilized in later chapters to analyze



Source: Navy Program Manager's Handbook

Figure 3.1 Impact of Design Decisions on LCC

the procurement alternatives for GPS. In addition, although seldom used in this manner, LCC estimates can be structured to compare the economic and overall readiness impacts provided by competing programs. In this manner they can support both programming and budgeting decisions as the necessary winnowing decisions take place at the service and DOD levels. This is a more "global" use of the LCC technique and could be termed "management-oriented LCC analysis."

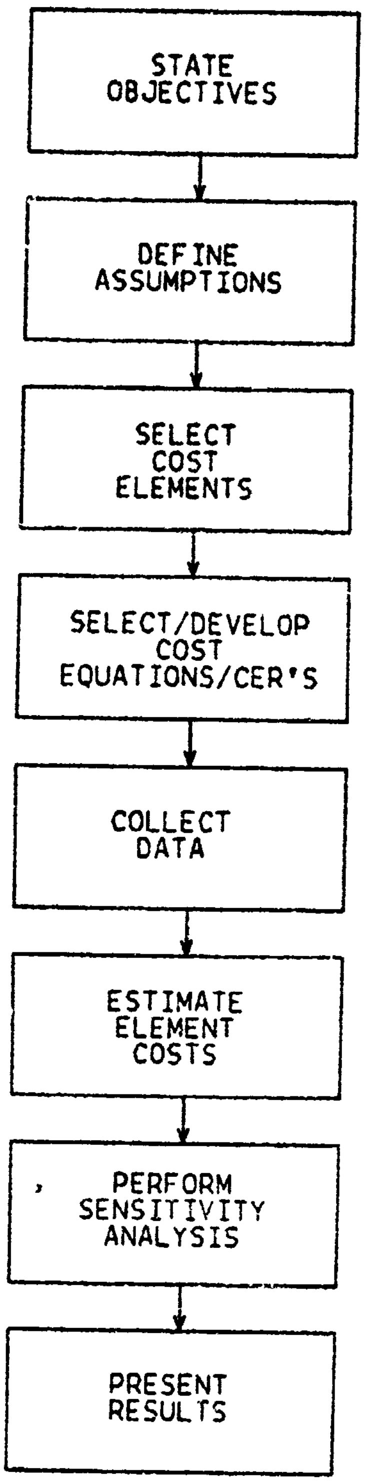
C. LIFE CYCLE COST METHODOLOGY AND STRUCTURE

Important to an understanding of the analysis presented in subsequent chapters is that the reader be familiar with the methodology within which an analysis takes place. Further, knowledge of the structure within which economic information is summarized and aggregated is particularly pertinent.

General DOD economic analysis methodology is described in DOD instruction 7041.3. Design-to-Cost direction is found in DOD instruction 5000.28. Although there is no DOD level directive on LCC, the Office of the Secretary of Defense (OSD) Cost Analysis Improvement Group (CAIG) has provided guidelines for the preparation and submission of such cost estimates to the review process. Life Cycle Costing within the Navy is governed by Secretary of the Navy (SECNAV) Instruction 4000.31. These directives provide an infrastructure upon which economic analysis, including LCC analysis, takes place. This infrastructure has helped promote standardization in the methods by which analyses are performed. In so doing, both the format and output of the studies have also been somewhat standardized.

1. LCC Analysis Methodology

Figure 3.2 describes the common LCC methodology issued by both the Navy and Air Force in at least one of their LCC manuals [Ref. 14]. The methodology may be viewed



Sources: Air Force TRI-TAC LCC Manual and NAVMAT LCC Guide (DRAFT)

Figure 3.2 Life Cycle Costing Methodology

as a flowchart which depicts the organization required to produce an LCC model. These eight basic steps are not a serial process, rather they are interdependent and interactive. Most LCC analyses will include these general procedures in greater or lesser detail dependent upon analytical requirements. Each step will be briefly discussed in the following sections. It should be noted that this study will not pursue the formal development of an LCC model for GPS user equipment. Instead it will use the ARINC Research cost model which was developed for the GPS program. However, upon review, it appears that the development of the ARINC model closely followed these basic steps.

a. State Objectives

The first step of the methodology is to identify, formulate, and state the analytical objectives of the study. The central purpose of this step is to define and limit the scope of the analysis.

b. Define Assumptions

Every cost study requires the identification of assumptions to reduce the necessity for specific, detailed cost inputs. Detailed and accurate cost inputs are seldom available to the decision maker early in a developmental program. The adoption of assumptions allows the analyst to set parameters around uncertainties and proceed with the analysis.

It is important that the assumptions be formulated by those personnel closest to and most experienced in the areas in question--typically not the analyst himself. As an example, logistics personnel should formulate the support concept assumptions and acquisition strategies should come from the Program Manager.

c. Select Cost Elements

The identification of cost elements is an important step. It involves the listing of all program costs into a structure which provides assurance that all major costs are counted, that costs are not double counted and that the cost elements are consistently and clearly defined.

d. Select and Develop CER's

Now that a framework has been defined for the analysis and cost elements defined, actual dollar cost estimates for each element must be developed. This is done through the use of cost equations and cost estimating relationships (CER's).

The cost equation in its simplest form is an algebraic expression which relates the value of specific cost categories to specific cost generating variables. For example, the cost of Initial Spares (a cost element), for an avionics procurement may follow the cost equation:

Cost of initial spares = .2 x Total Cost of Avionics Sets

where, .2 = Percent of avionics sets to be spared

These cost equations are frequently heuristic and the estimates are usually updated as more definitive cost data are generated.

Cost estimating relationships, as opposed to cost equations, are generally more complex equations combining the effects of several independent variables. These relationships are derived by statistical and regression analysis techniques applied to historical data. Several types of CER's are frequently utilized by estimators. They include parametric CER's, industrial engineering CER's, analogy CER's and expert opinion CER's.

e. Collect Data/Estimate Element Cost

Data collection represents perhaps 90 per cent of the total work effort in LCC analysis [Ref. 15]. The data is utilized as input to the cost equations and CER's to estimate individual cost elements. The actual collection of data is preceded by the definition of data requirements and the identification of potential data sources. Finally, after the data has been obtained it must be classified in terms of uncertainty and reliability.

f. Perform Sensitivity Analyses

Since every cost estimate is subject to some error it is important that the total impact of this error be defined. Sensitivity analysis provides the decision maker the ability to vary the values of major cost-drivers through

the cost model. This procedure defines the cost variances likely to be incurred if errors in important cost element estimates exist.

Sensitivity analysis is generally performed at two different levels of estimation. The first is at the cost equation or CER level. At this level sensitivity analysis attempts to describe the possible effects if a developed CER fails to "capture" or accurately describe that element of cost which it is attempting to estimate. The second level of sensitivity performance is on the aggregate total LCC. Here sensitivity analysis helps define the cost effects of all CER's if they interact in a manner which produces an inacurrate overall estimate of true system cost. This sensitivity of the total estimate is important since errors in individual CER's may be additive in one direction or another or their interrelationships may be disguised by offsetting errors.

In either case, estimates seldom reflect final costs. An important point in the expression of estimated costs is that the analyst define the uncertainty associated with the estimates. The two methods most used for qualifying cost estimates are either by establishing statistical confidence intervals for the parameter estimated or by using three different levels of confidence for estimation. In the case of confidence levels, a pessimistic, an optimistic and a

most likely projection are made. Sensitivity analysis is simply a method utilized by analysts to place bounds on the uncertainties associated with their cost estimates.

Sensitivity analysis is frequently used to define likely costs in the O&S area if performance trade-offs are made. For example, "what would be the additional O&S costs incurred over a system's life if mean time between failure (MTBF) specifications were lowered by "X" amount for the equipment?" This technique is a valuable tool which informs management of the costs associated with various alternatives and, more importantly, the possible costs associated with errors in either cost estimation or the defined assumptions.

g. Present the LCC Estimate

A properly completed LCC analysis will identify those costs associated with the unique situation defined by the objectives of the study. It is a result highly dependent upon the specific assumptions associated with those stated objectives. Therefore, it is imperative that the cost estimates always be closely associated with the study from which they are drawn.

The actual format of an analysis can take many shapes, dependent upon its intended recipient, but should as a minimum, describe individual cost elements and cost categories by both annual and total costs [Ref. 16]. In addition the estimates should be presented in an escalated, de-

escalated and constant year dollar format. The overall format of the presentation is specified by the overlying cost analysis instructions. That format is described in the following section.

2. LCC Presentation

The overlying directives have dictated the acceptable methodology and the OSD's Cost Analysis Improvement Group has identified the acceptable output format for the cost estimates they review prior to a Defense Systems Acquisition Review (DSARC). Conceptually sound estimates presented in standardized formats allow expeditious review of programs and should improve the probability that the lowest LCC systems are selected for development and production.

a. CAIG Cost Category Format

The format approved by the CAIG identifies the total system life cycle cost by subdividing the cost into three major categories of aggregation. The principal areas are:

1. Research and Development--This category, described by 100 series numbers in cost presentations, identifies the contractor and in-house costs associated with Research, Development, Test and Evaluation (RDT&E).

2. Investment--This category, described by 200 series numbers in cost presentations, identifies the contractor and in-house costs required beyond the development stage to procure and introduce into operational capability a new system.

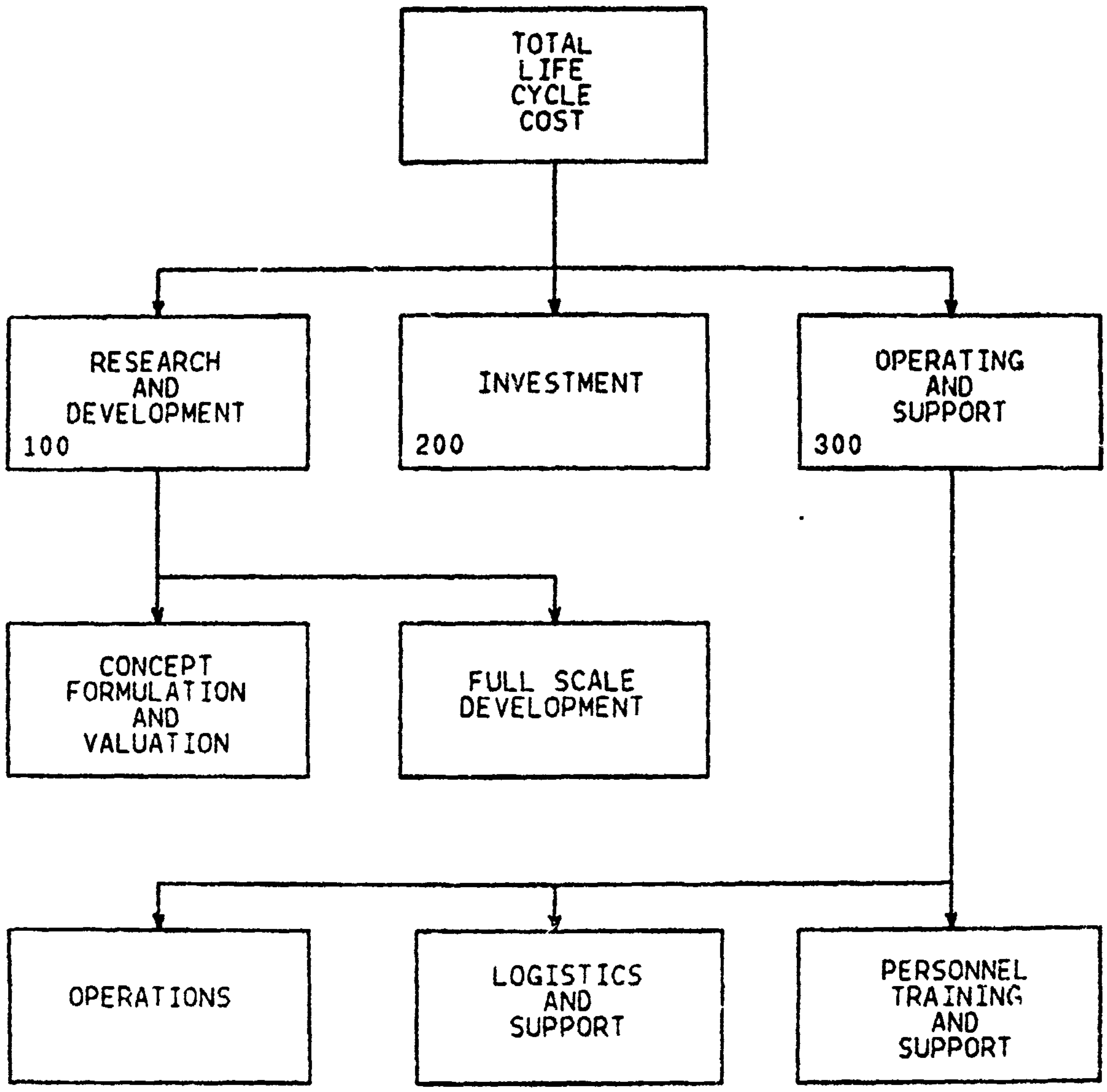
3. Operating and Support--This category, described by 300 series numbers in cost presentations, identifies the

costs required to operate, maintain and support the equipment or system during the operational phase.

These relationships are depicted in Figure 3.3 [Ref. 17]. The basic categories previously defined can be broken into subcategories and they in turn into individual cost elements.

b. Cost Element Format

The cost elements identified for estimation are aggregated under their applicable categories and costed on an annual basis for some number of future years. An example of a simplified cost element structure format is provided as Appendix A. Appendix B, builds upon the simple structure of Appendix A to describe a more detailed cost element structure--the structure developed by ARINC Research to aggregate the LCC estimates for the Navy's cost of GPS user equipment. Appendix B is a presentation of the annual and aggregate cost estimates for a single host vehicle. Each Navy vehicle has had a similar estimate prepared. In the case of the Global Positioning System, user equipment cost elements are costed from the current year through the year of the final operational equipment installation. Note that the presentation has been totaled horizontally by cost element and vertically by annual cost applicable to the host vehicle. Appendix C defines the individual cost elements in greater detail.



Source: Air Force TRI-TAC LCC Manual

Figure 3.3 CAIG Life Cycle Cost Structure

D. SUMMARY

This chapter has sought to provide the reader with the requisite knowledge to assimilate an LCC analysis later presented in this thesis. To do so three major topics were discussed.

First, pertinent definitions were presented to familiarize the reader with the types of costs incurred in the acquisition of military systems. The important evolution of cost as a major system evaluation criterion and LCC as a managerial tool were also discussed.

There followed a presentation of the specific use of LCC analysis as a cost estimating technique. Finally, the importance of standardization in LCC estimates was emphasized. To that end the Cost Analysis Improvement Group's cost structure and cost analysis format were described.

The forthcoming chapter utilizes the background LCC information herein discussed and describes more specifically the LCC model developed for cost estimation of the Global Positioning System's User Segment.

IV. ARINC USER SEGMENT COST ESTIMATION

The objective of this chapter of the study is to review the cost estimating models that are used in the analysis for determining the life cycle costs of Navy GPS user equipment.

Since the GPS program involves a broad range of hardware and software applications in addition to varied operating environments, it presents a unique challenge in cost estimating. Because of these complexities, the Automated Cost/Budget Estimating Network (ACBEN), was developed by ARINC Research Corporation for the NAVSTAR program. It is a system of computer programs, subroutines and information channels. The system is comprised of the following elements [Ref. 18]:

- Data base management system,
- Management information system,
- Budgeting models,
- Life cycle cost algorithms,
- Cost estimating relationships, and
- Cost control methodologies.

The ACBEN that has been developed for the Joint Program Office is used to determine tri-service cost estimates for the User Equipment Segment. Specific assumptions and estimating differences, as they relate to each particular service, are isolated within the database allowing each

service to interact with the system as if it were a virtual model for their individual use. This approach provides a single, controlled, approved data base from which specific life cycle costing information can be obtained for each service under varying conceptual considerations.

The following sections of this chapter will present an overview of the baseline data and methodologies that are incorporated within this ACBEN for use in estimating investment, installation, and operating and support costs for the user equipment to be installed in Navy host vehicles.

A. USER EQUIPMENT

One primary input of the GPS LCC model is the system architecture of the user equipment. The baseline data [Ref. 19] maintains the three previously mentioned receiver model considerations that will be installed in a variety of host vehicles to provide mission critical navigation data. They are the low dynamic, man-pack set; medium dynamic, two-channel set; and the high dynamic, five-channel set. These three configurations will accommodate the navigation requirements of all the platforms that are identified to receive Phase III production systems.

1. Set Architecture

The architecture for the Phase III user equipment will be comprised of several integral components, each of which will be designed for usage on multiple platforms.

These common components are referred to as Line Replaceable Units (LRU's). LRU's are themselves composed of common hardware replaceable modules and chassis components known as Shop Replaceable Units (SRU's). This architecture approach is consistent with the overall strategy of minimizing the number of platform unique elements, through the use of common modules, while satisfying the varying host vehicle unique requirements.

The integration of GPS UE into Navy/Marine Corps platforms will be achieved by selecting the appropriate combination of LRU's necessary to meet individual platform requirements. Tables I, II, and III describe the nominal user equipment LRU's for typical GPS applications onboard Navy platforms.

2. LRU Descriptions

To aid in reader understanding, the following provides a general description of the GPS user equipment LRU's.

a. Receiver Processor Unit (RPU)

This LRU will consist of a number of modules assembled to perform the functions of signal processing, data processing, and power conditioning and distribution. Although three general types of RPU's have been ir coduced in this study, only the following two types are pertinent to our analysis. They are the:

Table I

Nominal User Equipment LRU's, Aircraft

Platform Type	LRU
Aircraft/Rotary Wing (1)	High Dynamic RPU Medium Dynamic RPU Typical FMI Test FMI (2) CDU CRPA CRPA Electronics FRPA FRPA Electronics

Notes: (1) A typical GPS UE configuration for aircraft will consist of the following RPU's: either a High or Medium Dynamic RPU, FMI (if required), Test FMI (for P-3C/EP-3 only), CDU, either a top mounted CRPA or FRPA and its associated electronics, and a bottom mounted FRPA (if required).

(2) In the final design, the Test FMI may be functionally incorporated in the FMI.

Source: NADC Integration Concepts for Aircraft

Table II

Nominal User Equipment LRU's, Ships

Platform Type	LRU
Surface Ship	Master Control Unit (1) Remote CDU and Housing Antenna and Antenna Electronics (2) CRPA/Antenna Electronics (2) FRPA/Antenna Electronics (2)

Notes: (1) Master Console Unit consists of a Medium Dynamic RPU, FMI (if required), Test FMI, CDU, and Enclosure.

(2) Either a CRPA or a FRPA will be used aboard surface ships.

Source: NADC Integration Concepts for Ships

Table III

Nominal User Equipment LRU's, Submarines

Platform Type	LRU
Submarine SSN	Master Console Unit (1) Remote CDU and Housing Antenna (modified AN/BRA-34) Antenna Electronics (SSN)
USNS VANGUARD	Master Console Unit (1) Remote CDU and Housing Antenna (modified AS-1284) Antenna Electronics (SSBN)

Notes: (1) Master Console Unit consists of a High Dynamic RPU, FMI, CDU, Power Supplies, Test FMI, and Enclosure.

Source: NADC Integration Concepts for Submarines

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1. The two-channel RPU, which employs dual-channel sequential tracking operations. It is a medium-dynamic unit, designed for use in low performance aircraft and ships.

2. The five-ch^nnel RPU, a fast acquisition, continious tracking unit designed for high performance aircraft and nuclear submarines.

Each of these RPU's perform the following functions as specified in Systems Segment Specificiation SS-US-200 [Ref. 20]:

- Receive and amplify signals transmitted by all visible satellites.

- Select and acquire signals from four desired satellites.

- Track the acquired navigation signals (four simultaneously for the five-channel, four sequentially for the one and two-channel sets).

- Extract data contained in the received satellite data.

- Measure signal propagation error.

- Provide resistance to jamming.

- Compute position, velocity, and time.

- Generate self test signals for UE fault isolation.

- Provide additional functions as required by platform configuration and mission. (i.e., Inertial Aiding, etc.)

b. Antenna/Antenna Electronics

The antenna and antenna electronics are separate LRU's. The antenna performs the signal reception functions for the UE and consists of all receptor elements, radomes, filters, RF amplifiers, and control elements required for antenna operation. The host vehicle may require a single antenna, or, for an all attitude capability, dual antennas. There are two generic types of antennas available for use as part of the UE. They are the fixed reception pattern antenna (FRPA), and the controlled reception pattern antenna (CRPA). The choice of antenna for each host vehicle is dependent upon vehicle dynamics and antijamming (A/J) requirements.

The FRPA is an omni-directional antenna with a deep null at the horizon. Under ambient jamming and radio frequency interference (RFI) conditions, the CRPA has a similar pattern. However, under jamming conditions the CRPA's electronics will detect the direction of the jamming source and alter the reception pattern by placing a null in the direction of the jamming source. The number of jamming sources that can be nulled is dependent on the number of

elements in the antenna. The operation of the CRPA is self-contained and does not require any host vehicle information.

c. Flexible Modular Interface (FMI)

The Flexible Modular Interface will provide the interfacing function between the RPU and the platform. The FMI will provide the GPS UE with the capability of interfacing with both analog and digital platform equipment and may contain a microprocessor for data manipulation where required, e.g., as an aide in interfacing GPS data with the platform's central computer or weapons computer. The FMI for each platform will be designed to meet the unique requirements of that platform. These unique designs will be based on the requirement to utilize, where possible, replaceable components common to all FMI's. This functional partitioning approach will allow the use of common LRU's across many Navy and tri-service applications while supporting platform specific requirements in the platform unique FMI's.

d. Control Display Unit (CDU)

The GPS Control Display Unit provides the operator with the capability to control the UE, input data and observe UE generated outputs. The GPS CDU contains operating controls, a data entry keyboard, and alpha numeric displays. The CDU is functionally partitioned from the RPU to permit operation of the sets without the CDU in such

installations where it is desired to control the GPS UE via the platform's existing data bus/control system.

For shipboard and nuclear submarine applications, the CDU will be mounted with the RPU. In addition, a remote CDU will be provided where required. For aircraft applications, the CDU will generally be mounted in the cockpit or at the navigation operator's console. Remote repeaters will be provided where required.

e. Test Flexible Modular Interface (Test FMI)

The Test Flexible Modular Interface provides the means of extending the internal fault isolation capabilities of the GPS UE from the LRU to the SRU level. The use of the Test FMI will allow for organizational/intermediate level of maintenance to be performed onboard the platform. The Test FMI shall be included in all shipboard applications. The P3-C/EP3 are the only Navy aircraft presently scheduled to [illegible] a Test FMI as part of the GPS UE.

<u>LRU Integration Summary</u>

To summarize, each user set will contain specific LRU's such as receiver-processors, power supplies, and antennas. These user sets will be integrated into host vehicles by means of additional LRU's, e.g., control display units, and flexible modular interfaces. This will result in significant commonality between the LRU's of various sets of different platforms.

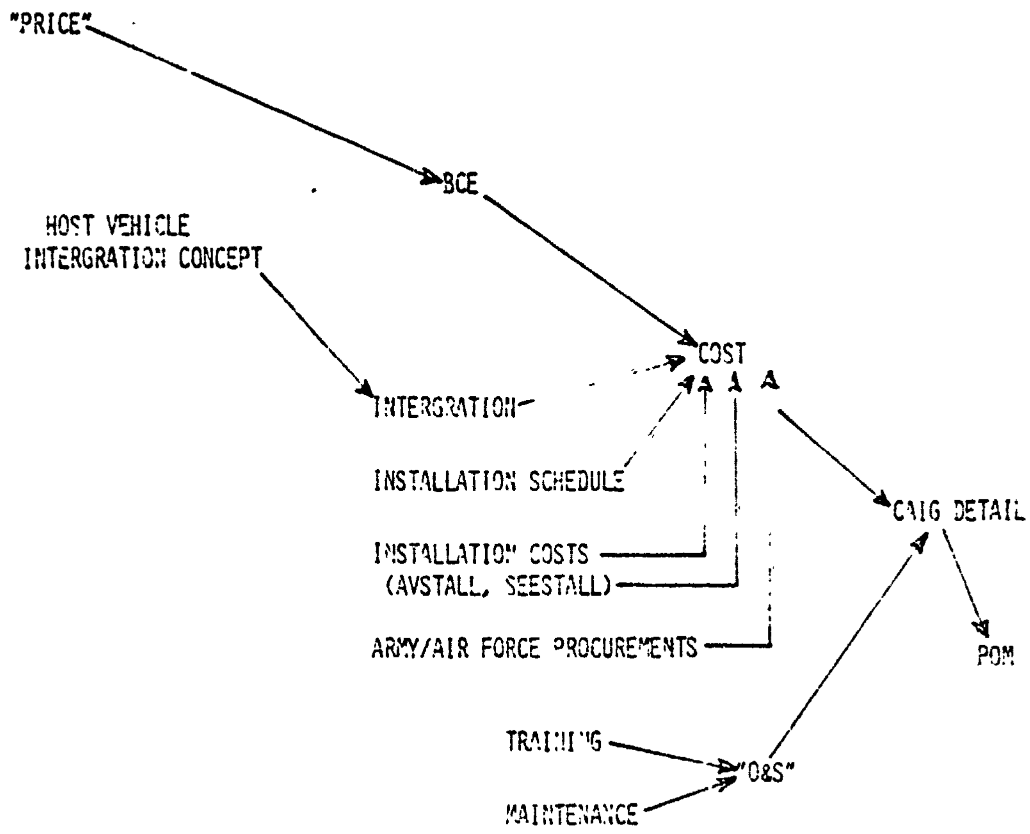
The high commonality of user equipment in different host vehicles provides a useful base from which costs for investment, platform installation, and operating and maintenance can be estimated. It is from this baseline integration concept that cost model development and analysis proceeds.

The technical baseline used in this cost estimating model is documented in ARINC Research Corporation Engineering Note 1727-79-46 (change 1). This engineering note defines the composition of the UE sets for each vehicle type and the necessary actions for installing the set in each type host vehicle.

B. COST MODEL PRESENTATION

This and the following sections describe the various ACBEN cost estimating models, their methodologies, and their applications in the generation of GPS user equipment cost estimates.

The approach will be to break the ACBEN into three major cost estimating segments: UE Production cost estimates, Installation cost estimates, and Operating and Support cost estimates. As depicted in Figure 4.1, these segments break at logical points within the ACBEN system and provide a natural segregation for isolation and discussion of each.



Source: Joint Program Office

Figure 4.1 ACBEN Cost Generation

Each following section will be subdivided to discuss the technical approach used to develop the cost model, a general description of necessary cost estimating relationships and throughputs, and model application and interface within the system.

The cost estimates are performed at the detailed CAIG cost element level for each host vehicle type. The scope of each cost element is defined in ARINC Research Corporation Engineering Note 1727-79-41A. For ease in reference, selected portions of this engineering note are contained in Appendix C.

C. LRU FIRST UNIT PRODUCTION COST ESTIMATE

As mentioned GPS user equipment sets for this study's purpose are considered to consist of assemblies of defined LRU's. The model utilized to estimate the cost contribution of these LRU's to the GPS sets is the RCA Corporation developed PRICE (Programmed Review of Information for Costing and Evaluation) Model [Ref. 21].

The PRICE computer cost model provides the estimates of system acquisition costs--particularly those costs associated with development and production. As a model, PRICE uses historical data, either experienced or observed, primarily from RCA sources. It allows for certain new advances in technology and inflation in developing cost estimates. The model is parametric and functions with linked algorithms to formulate cost estimating relationships. In addition the model employs learning curves. It has the capability to perform sensitivity analysis as parameters and variables are adjusted. The data inputs are principally physical characteristics of the design concept, including size,

weight, type of components, power dissipation, etc. Proposed production schedules, quantities and prototype requirements are also included. The software for PRICE is established on commercial time-sharing systems. Of note is that the model is "opaque", i.e., the user can see neither the historical data nor the CER's used, only the results. This is done deliberately to protect the proprietary nature of the model.

1. PRICE Estimates

Within the ACBEN, the RCA PRICE Model is being used to develop generic estimates of Phase II and Phase III user set contractor costs for all LRU's. The numerical outputs of the model relating to the "expected" value, designated as cost range-center, are being used in the development of cost elements. Specific data derived from the PRICE outputs for GPS include cost values for:

- Drafting,
- Design,
- Systems Engineering,
- Project Management,
- Documentation/Data,
- Tooling and Test Equipment, and
- Prototype Average Unit cost.

In Phase III applications, the data specifically output from the PRICE Model will be the LRU first unit production cost. These cost estimates are to be used as basic

cost data, as well as throughput to the ARINC Research Corporation AVSTALL and SEESTALL Cost Models discussed below. The reader should note that these cost estimates reflect the use of learning curves to show cost improvement as a function of increasing production quantities.

Learning curve data promulgated by the program office to be applied in the Phase III RCA PRICE Model computations are as follows:

Element	Learning Curve Slope
UE Sets	.93
UE Set Spares	.93
Installation Kits	.93
Installation Labor	.80

In all cases where learning curves are to be applied, the methodology will be to calculate the average cost for each year's quantity as a function of first unit cost, quantities, and learning curve slope [Ref. 22].

To summarize, the investment cost of user equipment sets, (identified in the GPS cost structure as Group B Kits), is derived from the RCA PRICE Model. The ACBEN's cost estimate is in turn based upon individual components, total procurement quantities for all three services (at the individual component level), learning curve application and the first unit cost of the specific component. User equipment procurement lead time is two years prior to planned installation onboard a host vehicle.

As will be shown during the analysis in subsequent chapters, this first unit production cost is the one input which yields the greatest impact on total system cost. Because of its significant influence upon the conclusions of this study, this estimate will receive primary emphasis in the sensitivity analysis.

D. INSTALLATION COST ESTIMATE

This section will describe the two installation cost estimating models developed by ARINC Research Corporation for use with the NAVSTAR Program. They are the Avionics Installation (AVSTALL) Cost Model, used to determine aircraft-peculiar costs of installing avionics equipment into military aircraft, and the Shipboard Electronics Equipment Installation (SEESTALL) Cost Model, which determines estimated costs and labor requirements for installing electronic equipment aboard Navy ships.

1. AVSTALL Cost Model

The cost of modifying Navy aircraft for GPS UE sets is estimated using the AVSTALL cost model. AVSTALL employs a combination of cost estimating relationships and throughputs to estimate the costs related to an aircraft modification. The CER's were developed from an extensive technical and cost data base of more than fifty avionics modification programs of Air Force aircraft.

AVSTALL estimates the total cost of an aircraft modification through a combination of generalized CER's, specialized GPS CER's, and throughputs. Only aircraft-peculiar costs such as installation labor, installation modification kits, engineering, testing, documentation, support equipment, and initial spares are estimated using the basic AVSTALL CER's. User set costs, RDT&E, and sustaining engineering are throughputs to the basic AVSTALL. The most prominent throughput which results from the RCA PRICE Model is the user kit cost which accounts for more than fifty percent of the total aircraft modification cost [Ref. 23].

2. <u>SEESTALL Cost Model</u>

The development of SEESTALL was patterned after that of AVSTALL. However, the development of SEESTALL differed from AVSTALL because of two major differences between aircraft and shipboard installations--the degree of configuration control and the quantity of installations having common electronics. Both of these factors are considerably lower for ships than for aircraft. While a common modification kit could be prototyped, tested, and produced for a large number of aircraft of a type, each Navy ship has its own characteristics and unique equipment. Even though several ships may be of the same class, their internal layouts almost always vary. With these differences in mind, ship data were analyzed by ARINC Research Corporation to

produce a viable cost estimating model for shipboard installations.

SEESTALL estimates the total cost associated with a shipboard installation by a field electronics installation team, (Tiger Team), using as input a combination of fixed-fee items, man hour and labor action interrelationships, and a variety of material requirements. Hardware-related information that must be known before exercising the model includes quantities and types of cables, equipments, panels, and installation descriptions.

The model revolves around man-hour estimates, and understandably the cost of labor is a critical input to the model. Variations in labor rates will have the most dramatic impact on system installation cost. By computer modeling, the placement of LRU's can be varied and best fit options analyzed for lowest installation costs [Ref. 24].

E. OPERATING AND SUPPORT BUDGETING MODEL

As with the investment cost estimates, the determination of operating, logistics, and other support costs is also a particularly difficult task.

Estimates of future O&S costs are beset by uncertainties from many sources. Some of them are the:

- Quality of data available,
- Methods used to estimate costs,
- Decisions yet to be made about design or use,

- Changes in scope of the acquisition program (e.g., quantities, cost or schedule,

- Technical or technological problems encountered during development,

- Operating and support environment, and

- Equipment characteristics that will become evident only after years of operational experience.

To meet this demand, the O&S Budgeting Model (also developed by ARINC) is structured to provide a variety of operational and support output cost estimates for both Navy aircraft and shipboard applications. To allow for the necessary uncertainties to which O&S estimates are subjected in the early phases of program conceptualization and development, this model has been updated and revised as the program has progressed. It is based upon an operational plan delineating operations, integration, operating environment, force composition, deployment schedules, personnel, and other factors. In addition, specific model enhancements and improvements to existing algorithms are taking place to provide for a more "realistic" O&S cost estimate.

The Budgeting Model is structured to provide yearly cost estimates for both aircraft and ship installations of the GPS system. The order of evaluation for each aircraft or ship is:

- Determine the LRU assignments.

- Identify annual operating hours for each host vehicle for the number of years to be included in the evaluation.

- Calculate all O&S cost elements.
- Summarize all O&S cost elements by year.

These steps are repeated for each subsequent host vehicle. From these data, annual summaries of O&S costs for all host vehicles are provided.

1. Cost Elements

O&S cost elements are broken into a three tier hierarchy. The first tier segregates maintenance costs into below-depot and depot level costs. The first subordinate hierarchy addresses cost differences resultant from maintenance of shipboard versus airborne user equipment. The second subordinate hierarchy, or third tier, disaggregates costs into labor and material elements.

Finally, support investment for replenishment spares, those costs incurred for parts lost or damaged beyond repair, are included and segregated for ships and aircraft. The maintenance material is evaluated separately at each maintenance level and is broken down to the SRU level.

2. Data Inputs

Data variables required to develop the budgetary cost estimates include, but are not limited to:

- Annual operating hours of each host vehicle,
- Attrition rate in operating hours for each SRU,
- Number of SRU's per each LRU,
- Average procurement cost of each LRU for each year,

- Mean time between failure of each LRU,
- Number and types of LRU's comprising each GPS set,
- Average frequency of required maintenance (organic, intermediate, and depot),
- Mean time to repair of each LRU in each GPS set,
- Standard hourly maintenance rates.

The "Variables Definition, Value and Sources" section of ARINC Engineering Note 1727-79-43 [Ref. 25] provides further data variable definitions and values. The above is presented as a generalized list of the input data variables used in this model. These data variable values are derived from information obtained from UE contractors and the Government.

F. COST PRESENTATION AND SUMMARY

This section will summarize by cost element the output of the ACBEN Cost Models. The presentation format will reflect that format which will be used in subsequent cost discussions.

As previously mentioned in Chapter III, ARINC has expanded the CAIG Cost Element Structure for aircraft, land vehicle, and ship systems and modified them to accommodate, in one cost element structure, all three types of vehicles. In its present form it allows for presentation of cost elements to develop, acquire, integrate, and support GPS for each service. The following summary will delineate the three

major cost categories and the computation of the cost estimates.

1. Cost Presentation

a. Research, Development, Test and Evaluation

These 100 series cost elements are throughput costs, normally provided to the model by the program office.

b. Investment

These 200 series cost elements are the acquisition costs of the system/equipment and of the provision for its support in its employed environment. It is the sum of Cost Elements 200 (System Investment) and 202 (Support Investment).

Cost Elements 201.1 series (Group A Kits), are throughput costs as derived from the AVSTALL and SEESTALL subroutines.

Cost Elements 201.2.1 series (Group B Kits), are based upon individual components, total procurement quantities for Air Force and Army as well as Navy, (at the individual component level), first unit production costs, and learning curve. Lead time for cost estimating is two years prior to installation.

Cost Element 201.2.2.1 (Sustaining Engineering), is 5% of the above Group B Kit costs.

Cost Elements 202.1.1 through 202.3.4 (Support Investment Costs), are throughput costs from the AVSTALL and SEESTALL subroutines.

Cost Element 202.4.3 (Group B Set Spares), is 20% of Group B Kits plus Sustaining Engineering (201.2.2.1).

Cost Element 202.4.4 (Training/Maintenance Training Sets/ Support Equipment spares), is 15% of 201.1.2 (Training Modification Costs).

Cost Element 202.4.4.1 (Training Modification Spares), is 15% of 202.2.1 (Maintenance Training Sets).

Cost Element 202.4.4.3.1 (Peculiar Support Equipment Spares), is 15% of 202.1.1 (Peculiar Support Equipment).

Cost Element 202.4.4.3.2 (Common Support Equipment Spares), is 4.2% of 202.1.2 (Common Support Equipment).

Cost Element 203.1 (Sets), is the same dollar amount as 202.4.3 (Group B Set Spares), but is computed concurrently with the installation schedule.

c. Operating and Support

These 300 series cost elements are the variable costs of operating and supporting GPS modified vehicles and manpacks, including contactor support. These costs are calculated by the O&S cost subroutine based upon deployment

schedules, failure rates, mean times to repair, personnel pay rates, training requirements, etc.

They are based on the same set architecture as used in the 200 series calculations. However, unlike investment cost determination the O&S cost elements are computed using CER's where the installation schedules are interfaced with host vehicle deployment schedules.

2. Summary

The ARINC Research ACBEN provides validated LCC estimates for Navy user equipment. These costs are based on a "synthesized" UE set developed from Phase II contractor set designs and data provided by the government. Virtual interaction with the database provides program management pe[illegible]el with life cycle costing information needed under varying conceptual considerations. The cost model output is in an approved CAIG format aiding POM submission requirements for the program.

V. GPS ALTERNATIVE PROCUREMENT STRATEGIES

The review and assessment of alternative procurement strategies is a responsibility placed upon defense acquisition managers [Ref. 26]. An intent of that responsibility is to encourage thorough consideration of the systems which meet the mission requirements for performance and schedule and, in addition, to determine which system fulfills those requirements at least cost to the government. This chapter provides a quantitative cost analysis of the current and two hypothesized procurement strategies for GPS user equipment.

There are two analytical goals for this chapter. First is the authors' attempt to quantify the costs of each alternative procurement and the cost differentials which exist between them. The quantification of the procurement costs is particularly important because it provides a common basis upon which the alternatives can be measured.

The second goal is to examine the quantified cost differentials themselves. Herein the "validity" or the "reasonableness" of the estimated differentials is tested. The question to be answered is, "Is the differential a 'true' difference among alternatives or is it only a mathematical function of an insensitive model?" Although the cost estimates will be presented at "face value," each projection

has been reviewed. Where estimates fail to react either logically or consistently to alternative proposals, the source of that inconsistency will be discussed.

The first section will be a discussion of the assumptions associated with the analysis. The framework for the analysis of individual alternatives will then be introduced. Thereafter each alternative will be sequentially presented and its associated costs will be identified and quantified. Finally a comparative cost analysis of the alternatives will be presented. First, however, a qualification on the scope of the analysis is in order.

It is the authors' intent to present in this and subsequent chapters, clear and concise cost projections for possible alternative Navy UE procurement strategies. It is not our goal to provide an additional independent cost estimate. Rather, the most current, available source has been used--estimates developed by the ARINC Cost Model previously described in Chapter IV. The output costs of that model are used as direct input to this study. It is likely that the specific values of estimated alternative costs will contain some error; however, the model should provide reasonable estimates of the <u>relative</u> cost differentials associated with the alternative procurement strategies herein hypothesized.

These cost differentials will appear quite significant at first review. However, as the analysis is developed in a later chapter, benefits associated with individual alternatives will be quantified and cost savings resultant from that analysis will be used to offset estimated differentials where appropriate.

A. ANALYTICAL ASSUMPTIONS

In addition to the model-peculiar assumptions discussed in Chapter IV, other assumptions relevant to our analysis require identification. Some of the assumptions noted below have already been discussed. However, for continuity the assumptions used in the alternatives analysis will here be stated or restated and later explicitly discussed.

The reader should recall that the scope of this study was restricted in previous chapters by the following assumptions:

1. The analysis concerns only the Navy procurement alternatives for the User Segment of the GPS,
2. Only procurements for those vehicles which require two or five-channel receiver-processor unit applications will be assessed, and
3. The single component which differs between the two and five-channel systems is the RPU.

In addition to these previously introduced restrictive assumptions, the discussion of two others will sharpen our focus on the Navy costs under each alternative procurement. These are:

4. Specific assumptions concerning the UE procurement, and

5. Adjustments for inflation and discounting.

Each of these assumptions will be amplified in the following paragraphs.

1. Independent Navy Procurement

Although the procurement of GPS UE is highly service interdependent, each service will individually decide upon which of their vehicles will receive the technology and, thereby, upon the total number of UE sets they require. The individual service quantity decisions will significantly impact the unit costs borne by all. Certainly a decision to procure relatively greater quantities of user equipment, either two or five-channel, should lower the average per unit costs of that system gaining increased production. This occurrence is due both to learning curve effects and to the reduction in fixed costs allocated per unit. However, if the increase in quantity of UE of one type is at the expense of a quantity decrease in the other, an offsetting cost increase can be expected for that system which has decreased production.

This study will not address the impact of its procurement alternatives upon the total DOD cost of GPS user equipment. Rather, it will attempt solely to identify the costs which would be borne by the Navy under each of the three procurement alternatives later discussed. To determine

the Navy cost resultant from the alternatives, it is necessary to constrain the Army and Air Force UE inventory objective estimates to a fixed quantity for both their two and five-channel procurements. The ARINC cost model does this by freezing all other service UE quantity estimates to those levels in the data base at the time the Navy cost estimations are generated. The UE set procurement estimates utilized in this study are at the UE levels established for the 1984 Navy Program Objectives Memorandum.

Additionally, the analysis also maintains the total Navy objective for UE at a constant level. It varies only the procurement levels of the two and five-channel systems. For example, were a procurement alternative to require redesignation of a formerly two-channel host vehicle (requiring the installation of 100 user sets) for receipt of five-channel units, the total Navy UE unit procurements would not vary. The 100 units would be added to the five-channel procurement and deducted from the total two-channel buy. By holding all other factors constant and varying only the Navy procurement "mix" of medium and high dynamic RPU's, resulting cost changes can be attributed to the Navy's specific procurement decision.

2. Assessment Restricted to Two and Five-Channel UE

As previously discussed, only the exchange of two-channel for five-channel capability will be addressed. Since

the five-channel RPU data output provides at least the minimum (and generally exceeds) input requirements for two-channel host vehicles, it is, for purposes of this study, technically considered a perfect substitute for the two-channel system.[1] The one-channel RPU, conversely, fails to provide the necessary input specifications required by either the two or five-channel host vehicles and consequently, is considered unsuitable as a substitute.

3. Emphasis on RPU Cost Differentials

It was stated in Chapter IV that the single major component which would differ in the replacement of a two-channel system with five-channel capability is the receiver-processor unit. This analysis will therefore emphasize the RPU cost differentials associated with the hypothetical procurement alternatives proposed.

The emphasis upon differential costs among alternatives is consistent with SECNAV Instruction 7000.14 which states in part, "...it is critical for analysis to focus on the amount of difference in those costs affected by alternatives (differential costs)." [Ref. 27] It further

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[1]The HD receiver-processor is allowed, by specification, to be slightly heavier (8 pounds) and longer (6.9 inches) than the MD RPU. This difference, when discussed with program office and contractor personnel, was considered a minor technical integration problem which could be overcome for all Navy applications.

emphasizes that in analyses presenting cost reduction alternatives it is important to identify only the relevant costs--those costs, both direct and indirect, which are affected by one of the alternatives under consideration.

4. Specific Procurement Assumptions

The specific assumptions which directly impact alternative costs are discussed below.

a. Successful Maturation of Designs

Significant design changes have occurred since the concept validation user equipment was developed. Currently, neither the two nor five-channel RPU's have been fully developed and minaturized to the form and fit factors required. Nonetheless, the authors assume that the RPU's will be successfully developed to meet all technical performance specifications defined for the system in program specification SS-US-200 [Ref. 28].

b. Quantity

The authors assume that the DOD UE quantities provided for the fiscal year 1984 budget estimate and described in Table IV below, reflect the total inventory objective which will eventually be procured. However, it is here cautioned that the total tri-service UE estimates have varied widely during the program's life and further changes can be hypothesized.

Table IV

DOD UE Procurement Quantity/Schedule

Fiscal Year	84	85	86	87	88	89	90	91	92	93	94	95	96	Total
Air Force MD*	0	0	0	0	0	500	777	877	738	273	239	0	0	3404
Air Force HD**	0	47	178	187	646	799	1237	953	631	193	95	0	0	4966
Army MD (only)	100	260	260	260	260	115	0	0	0	0	0	0	0	1255
Navy MD	0	0	0	329	690	622	359	239	91	25	11	0	0	2366
Navy HD	0	0	169	301	350	496	544	417	419	287	0	0	0	2983
Total Annual Procure-ment	100	307	607	1077	1946	2532	2917	2486	1879	778	345	0	0	14974

* MD - Medium Dynamic (2-channel)

** HD - High Dynamic (5-channel)

Source: ARINC data base

c. Schedule

The authors assume that the UE procurement schedule of Table IV accurately reflects the actual schedule by which UE will be procured by DOD over the life of the system. Inherent in this assumption is that the lead contractor selected for production and his follower will be able to meet the UE demand specified in the schedule. It should be cautioned that new vehicles will likely be introduced which require GPS capabilities and that priorities may change regarding the precedence of service receipt of user equipment and/or of host vehicle installation. Like quantity estimations, estimates for UE production schedules have undergone substantial change during the life of the program.

d. Learning Curve

As discussed in Chapter IV, user equipment hardware production learning curves are applied on the sub-component or SRU level. Because of the high commonality of many (80 percent) of the sub-components employed in the one, two and five-channel systems, the application of the learning curve at the sub-component level is made possible. A 93 percent learning curve has been adopted in the ARINC model and applied across all common modules for cost estimation [Ref. 29].

e. Economic Life

This cost analysis will encompass a 20 year period from FY 1984 through FY 2003. This includes a 16 year period of operational utilization (Navy initial operating capability (IOC) is expected in 1988), and at least a 7 year period of operation for all identified host vehicles (the last currently identified installation is in 1996). Although we use the term "20-year costs" it is not used in the classic sense. Here it refers specifically to the period from FY 1984 through FY 2003, rather than to a generic 20-year operating life cycle. The difference is that in this analysis, O&S costs are incurred for only the actual operating period of each installed user set.

The ARINC model only estimates annual costs through FY 1996, which is the last year of UE installation. Since O&S costs will continue through at least FY 2003, they have been extended through that year at the annual O&S rate for 1996. This simple extension of costs is possible because very little O&S cost change is experienced in the last year of the ARINC estimate. It is logical to assume that as annual investment costs slow and then stop in 1996, that O&S costs will grow at a reduced rate and finally level-off shortly after the time of the last investment.

5. Inflation and Discounting

The topics of inflation and discounting are subjects of never-ending controversy, particularly within the public sector. Nonetheless, they are topics which must be addressed in a cost analysis. In addition, the reasons for their use or lack of use require substantiation. The authors have elected to ignore, within the context of this study, the inflation of GPS user equipment costs. This is equivalent to stating that all costs, unless otherwise identified, are expressed in 1979 dollars--the year of DSARC II approval. However, the discounting of cash flows projected for this Navy acquisition will be conducted. The following paragraphs will more adequately describe the underlying reasoning for these decisions.

a. Inflation

As mentioned, inflation in the cost of GPS user equipment will be specifically ignored in this analysis. DOD Instruction 7041.3 directs consideration of inflation where it is determined to be important to the conclusions of a study [Ref. 30]. Several practical aspects of this analysis led the researchers to believe inflation of User Segment costs would yield little insight to the various alternatives' true economic cost.

As previously discussed, this analysis assumes that neither the total quantity of user equipment nor the

installation schedule will vary among alternative procurements. Since, in each alternative, the same basic commodity--avionics/electronics--is being procured, with a fixed total quantity and the same schedule, no need exists for different economic inflators. This would not be the case were two programs being considered which required expenditures for very diverse commodities. Simply stated, it is assumed each alternative's costs will be exposed to similar inflationary trends over the same procurement and system life cycle.

In addition, the inherent error in forecasting inflationary rates must be considered. Long a point of controversy, it can be assumed in this thesis that incorrect forecasting would have similar effects on each alternative, and, therefore, like the previous example, inflation would be irrelevant to a least LCC decision. Therefore, inflationary adjustments are considered inconsequential and irrelevant to this particular analysis. However, this does not reduce the importance of discounting, a discussion of which follows.

b. Discounting

Upon review of one vehicle's projected GPS user equipment expenditures, Appendix B, it is immediately evident that cash flows are both time-phased and accrue in slightly differing amounts. Each of the three alternatives expend fiscal resources at different rates. It is considered

important that the present value of each alternative be determined to more accurately describe the "real" differential costs among the three.

Appendix D, [Ref. 31] shows the 10 percent discount factors which were applied to ARINC developed cost projections. Only the relevant (Investment and O&S) costs were discounted in this study. The actual estimation and discounting of alternative costs are provided in the later sections of this chapter.

B. ALTERNATIVE ACQUISITION PROPOSALS

Three specific acquisition alternatives will be described in this section. Each will be sequentially introduced and discussed. Quantification of individual alternative costs will be provided by the ARINC cost model and estimates will be presented in a tabular format. After the presentation of all alternatives, the cost data will be compiled in a comparative format, emphasizing cost differentials, to show the effects of each alternative mix of two and five-channel systems upon total Navy cost.

Hereafter, the three alternatives will be referred to as "cases." Case I identifies the current procurement strategy proposed by the program office. This case segregates UE procurement into two and five-channel systems based predominantly upon host vehicle dynamic requirements. The exception to this is the submarine application which utilizes

the five-channel system because of that system's capability to obtain an initial navigation fix in relatively less time than the two-channel system. The HD system thereby minimizes the submarine's exposure to detection.

Case II is the first hypothetical alternative procurement. In this case all aircraft in the Navy inventory currently identified to receive GPS would receive a five-channel system. This option would disregard the lower dynamic requirements of helicopters and patrol/transport aircraft in favor of five-channel RPU commonality for aviation assets.

Case III is another hypothetical alternative to the current procurement strategy. In this case all Navy host vehicles currently identified for either a medium or high dynamic RPU would receive the high dynamic, five-channel system. The following paragraphs further describe these alternatives and present the economic cost of each.

1. Case I--The Baseline

Case I is the baseline case for this analysis. It is currently considered by the Joint Program Office as the most cost-effective means to provide GPS navigational capabilities to fleet users. It is also the procurement strategy which has been presented and approved in the budget and Five Year Defense Plan (FYDP).

a. Case I--Quantity/Schedule

Under the assumptions of Case I the Navy would procure the quantities of two and five-channel UE on the schedule described in Table V.

Table V

Navy UE Procurement Quantities/Schedules

CASE I

Fiscal Year	84	85	86	87	88	89	90	91	92	93	94	95	96	Total
MD*	0	0	0	329	690	622	359	239	91	25	11	0	0	2366
HD**	0	0	169	301	350	496	544	417	419	287	0	0	0	2983
Total	0	0	169	630	1040	1118	903	656	510	312	11	0	0	5349

CASE II

MD	0	0	0	115	271	93	13	8	9	18	11	0	0	538
HD	0	0	169	515	769	1025	890	648	501	294	0	0	0	4811
Total	0	0	169	630	1040	1118	903	656	510	312	11	0	0	5349

CASE III

HD+	0	0	169	630	1040	1118	903	656	510	312	11	0	0	5349
Total	0	0	169	630	1040	1118	903	656	510	312	11	0	0	5340

* MD - Medium Dynamic (2-channel)
** HD - High Dynamic (5-channel)
\+ Case III assumes an all HD procurement

Source: ARINC Data Base

b. Case I--Costs by Category

The cost data presented in Table VI identify the costs of Navy GPS user equipment aggregated by the three major cost categories described in Chapter III. Although the Research, Development, Test and Evaluation category is herein considered a sunk cost, its costs are initially included for information. Total user equipment costs are provided at the bottom of each column. This table is provided to give the reader an estimation of the expected "constant dollar," Navy cost of the GPS user equipment under varying case assumptions.

Table VI

UE Costs by Case and Category

(Constant FY 79 $millions)

		CASE I	CASE II	CASE III
RDT&E	(1XX)	$125.9	$125.9	$125.9
Investment	(2XX)	667.8	710.7	721.2
O&S	(3XX)	93.0	101.5	109.1
Total		886.7	938.1	956.2
(Less Sunk Cost)		(125.9)	(125.9)	(125.9)
TOTAL RELEVANT COST		760.8	812.2	830.3

Source: PRICE-based ARINC cost estimates

From Table VI, the total Navy cost of a Case I procurement has been shown to equal approximately $886.7 million (constant $FY 79) over its life. Reducing this

amount by the sunk costs for RDT&E of $125.9 million yields a net <u>relevant</u> cost to the Navy of $760.8 million.

2. <u>Case II--An Aircraft Common Procurement</u>

Case II substitutes all aircraft two-channel installations with five-channel RPU's. This case, originally proposed by members of the Navy GPS program office, displays prospects of benefits, particularly in the area of interoperability among carrier-borne aircraft. In addition, cost reductions are hypothesized from common aircraft RPU maintenance requirements and improved logistics supportability. These reductions are not included in the Table VI cost summary.

a. Case II--Quantity/Schedule

Under the substitution assumption of this case, the UE quantity changes reflected in the Case II section of Table V would occur. It should again be noted that the number of UE "sets" procured annually and the <u>total</u> Navy inventory objective for UE (5349 installed sets) remain the same as those presented in Case I.

b. Case II--Cost by Category

The "constant dollar" economic cost data presented in Table VI identifies the cost of the Navy GPS user equipment by the three major cost categories earlier discussed. The total costs estimated from the Case II alternative reflect a required Navy expenditure, in constant

FY 79 dollars, for user equipment excluding sunk costs, of approximately $812.2 million. A comparative analysis of case costs will be presented after a description of Case III.

3. Case III--Navy Common Procurement

Case III is a procurement proposal in which all Navy GPS host-vehicles currently identified for a two-channel installation would instead receive a five-channel system. This case was developed by the researchers as a logical extension of Case II. A review of those platforms requiring two-channel applications, (after conversion of all aircraft to five-channel systems--Case II), reveals only 538 vehicles or 10.06 percent of the Navy's currently identified vehicle inventory would utilize the medium dynamic system. A further expansion of the now Navy-wide perceived benefits and cost savings from interoperability and logistics supportability may be hypothesized to offset the expected increase in procurement costs.

a. Case III--Quantity/Schedule

This case departs from Cases I and II in that no two-channel UE would be procured. All two-channel RPU's would be substituted with five-channel sets. The schedule for Case III procurement is thus displayed on a single line in Table V. As with the previous case, the annual UE set procurement and total Navy inventory objective do not change from those quantities specified for a Case I procurement.

b. Case III--Cost by Category

The "constant dollar" cost data presented in Table VI depicts the estimated costs of the Navy's GPS user equipment. The reader is reminded that RDT&E costs are considered sunk, therefore irrelevant, and are herein presented only for a perspective of total UE cost under a particular case assumption.

The relevant constant year costs to be incurred by the Navy from this procurement alternative have been presented in this section. These estimates indicate selection of Case III as the procurement strategy would cost $830.3 million (excluding sunk costs), or $69.5 million above the Case I estimate. The specific areas of cost difference will be more fully explored as we begin the comparative analysis of the alternatives in the next section.

C. COMPARATIVE ANALYSIS OF PROCUREMENT ALTERNATIVES

In this section a comparative analysis of the previously defined procurement estimates will be presented. The quantification of differentials between case costs will be emphasized. It is particularly important that these differentials be identified because the benefit analysis presented in Chapter VII will be utilized to "offset" or balance these differentials where potential cost savings exist.

This analysis will begin with the comparison of both constant dollar and discounted total costs for each of the

three alternatives. Segregation of these costs into investment and O&S cost categories with both constant and discounted presentations then follows. Thereafter the comparison of significant differentials on a cost element basis will be provided, again in a constant and discounted basis. Unlike the previous section, RDT&E costs will henceforth be excluded from the analysis.

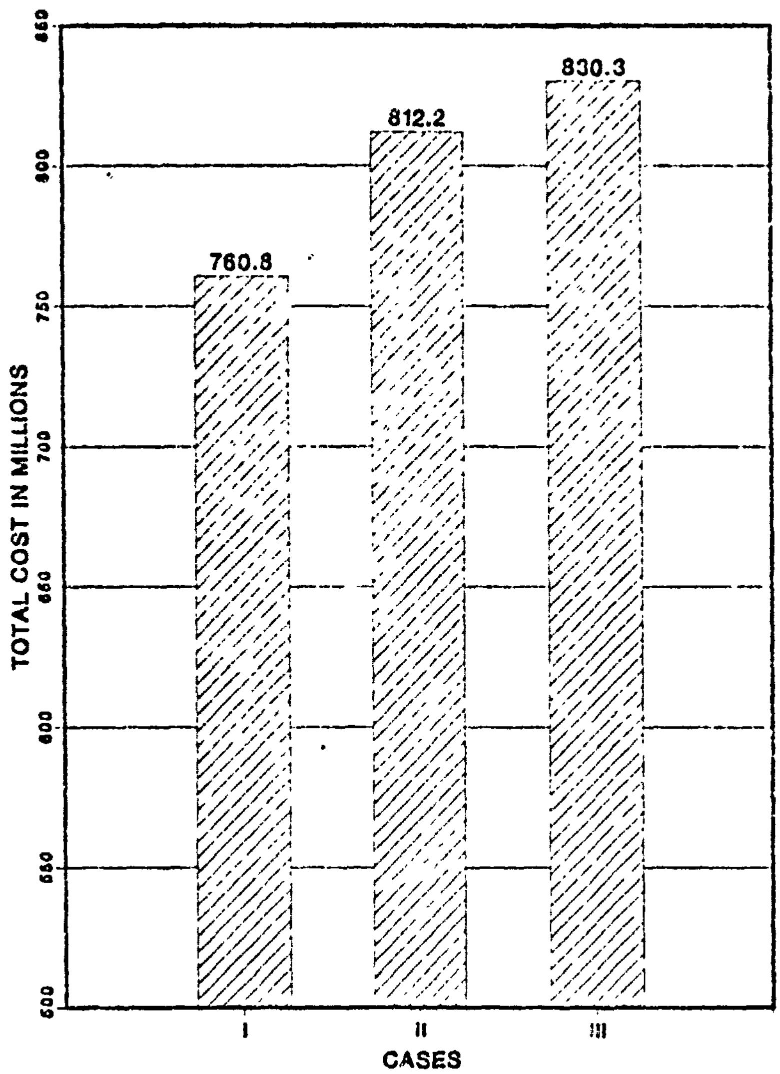
1. Total Alternative Costs

Through the use of the bar charts presented as Figures 5.1 and 5.2, this section describes the total costs of each alternative. It can be seen that the Case I assumption minimizes total life cycle costs in both the constant dollar presentation of Figure 5.1 and the discounted presentation of Figure 5.2. The percentage cost increase to procure user equipment under Case II or Case III assumptions is approximately 6.76 percent and 9.14 percent respectively, above the Case I alternative (constant FY 79 dollars).

2. Alternative Costs by Category

Again bar charts are utilized in Figures 5.3 and 5.4 to compare the alternative costs when disaggregated from the total to a relevant cost category basis. The review of these figures provides insight to the relative weighting of investment and O&S costs to the total estimated cost for the Navy's GPS User Segment.

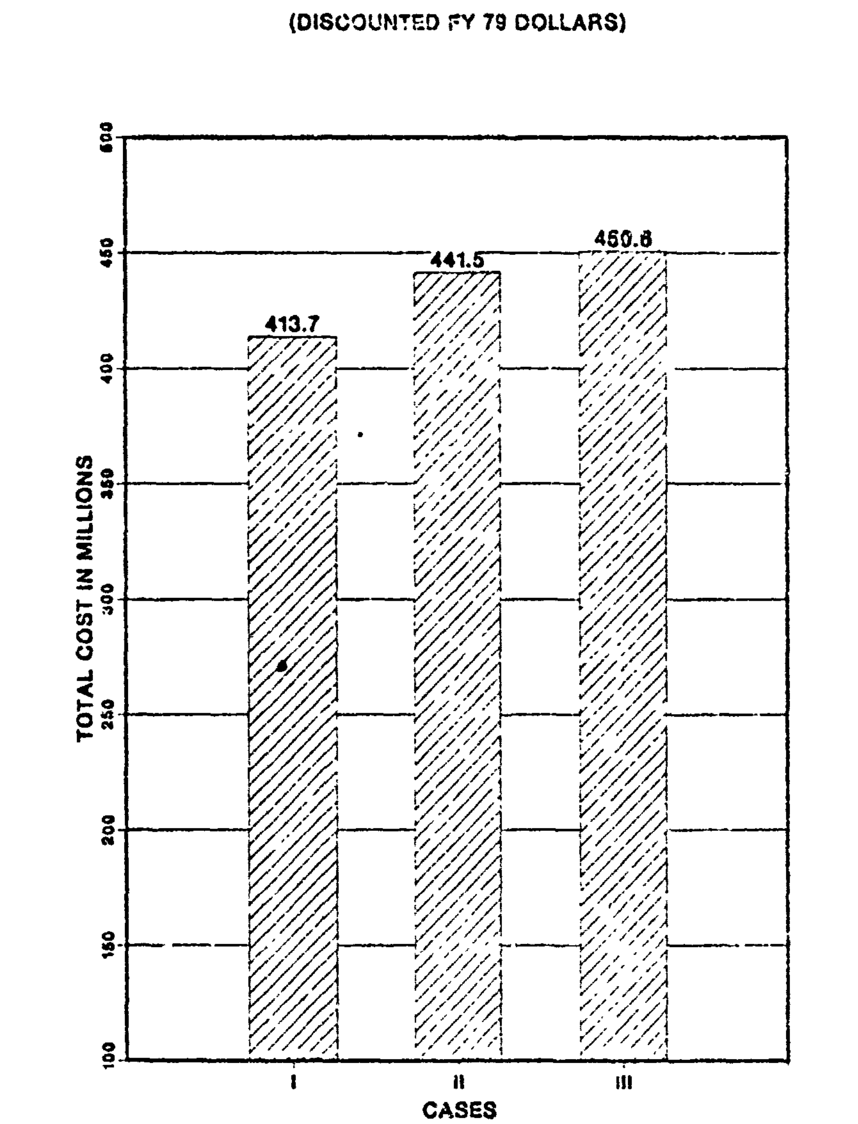
(CONSTANT FY 79 DOLLARS)



Source: PRICE-Based ARINC Cost Estimate

Figure 5.1 Total Cost of Alternatives

Analysis reveals several interesting relationships among the case costs and between the individual alternative's category costs. First, it can be seen that for this

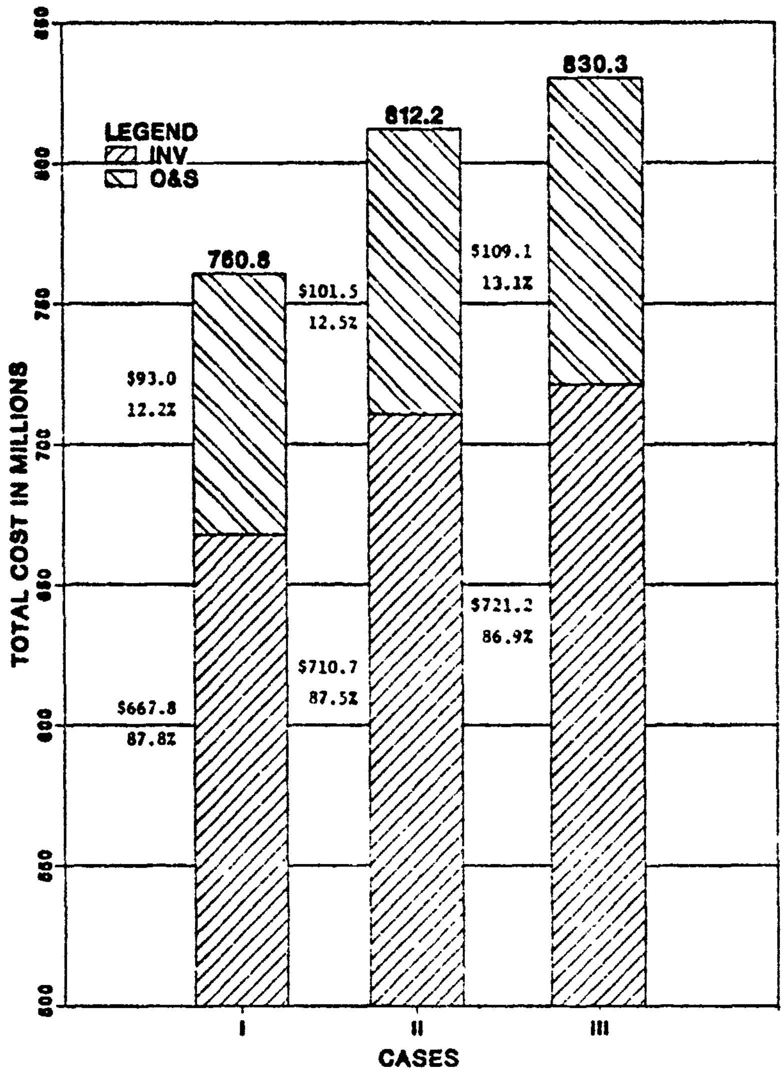


Source: PRICE-Based ARINC Cost Estimate

Figure 5.2 Total Discounted Cost of Alternatives

acquisition, under any alternative procurement, that the investment cost far exceeds the estimated O&S costs. Case III, described in Figure 5.3, provides the lowest percentage of investment to total cost at 86.8 percent.

(CONSTANT FY 79 DOLLARS)



Source: PRICE-Based ARINC Cost Estimate

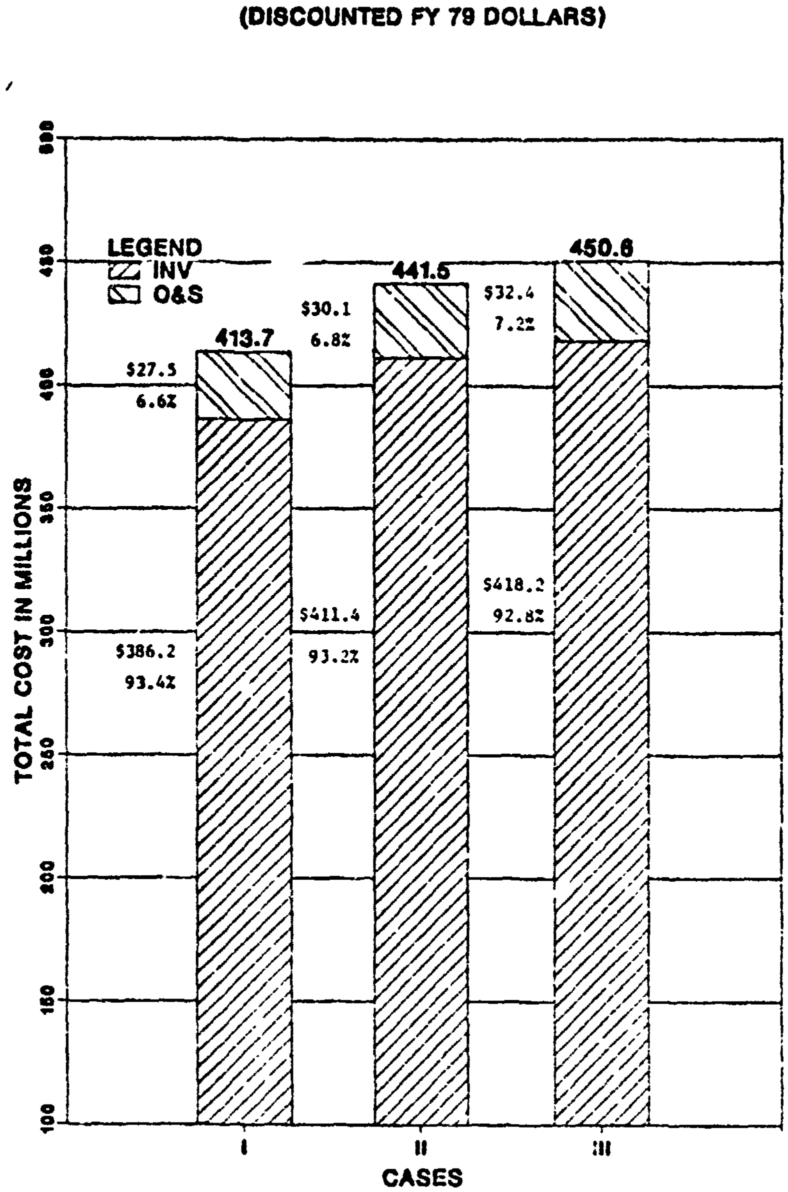
Figure 5.3 Alternative Costs by Category

A second point of interest is the relationship of cost differentials by category with the total differential estimates for a given comparison. For example, the total cost differential between Cases I and III was estimated in

Figure 5.1 to be $69.5 million (FY 79 dollars). Of that differential, $16.1 million (or 23.2 percent of the difference) is lodged in O&S costs while $53.4 million (76.8 percent) is found in the investment category.

Finally, when discounting is considered, the relative ratio of categorical to total relevant cost dramatically changes. O&S costs commence at system IOC in FY 1988, and continue (by assumption) through the last year for this analysis, FY 2003. The O&S estimates are therefore impacted to a larger degree by the relatively greater discounting in the outyears of the analysis than are the investment costs which (again by assumption) are expended by FY 1996. For this reason, the O&S costs in a discounted format, Figure 5.4, provide a relatively smaller proportion of total costs than they do in a constant dollar format, Figure 5.3. Consequently, in a discounted analysis of differential costs, the O&S costs are likewise a smaller percentage of the total cost differential.

In summation, every alternative's costs, whether in a discounted or constant format, display the dominance of Investment over O&S costs. Further, it can be seen that Case I costs, by respective category, are less than those of the Case II procurement, and that the Case II costs are, likewise, less than the respective category costs of the Case III alternative. To determine more precisely where the



Source: PRICE-Based ARINC Cost Estimate

Figure 5.4 Discounted Alternative Costs by Category

differentials originate within each category it is necessary to compare the relevant cost element estimates--those which show a difference under individual alternatives.

3. Alternative Costs by Relevant Cost Elements

Of the forty-seven Investment and O&S elements for which costs are estimated, only sixteen (4 Investment and 12

O&S) display cost differentials among alternatives. Many of the element differentials are small in comparison to the total differential between given cases. To ensure the more significant cost elements receive attention and are not masked by unnecessary detail, the authors have selected the ten cost elements (4 Investment and 6 O&S) which explain the greatest amount of cost differential between alternatives. The ten elements selected can be analyzed to explain, as a minimum, 98.49 percent of the total estimated constant cost differential between any combination of cases. The elements which have been identified as significant cost contributors are presented as Table VII.

Table VII

Significant Cost Elements

Cost Category	Cost Element Number	Cost Element Title
Investment		
	201.2.1	Receiver-Processor Unit
	201.2.2.1	Sustaining Engineering
	202.4.3	Group B Set Spares
	203.1	Sets
O&S		
	302.5.1.2	Below Depot Maint Matl Air (Int)
	302.5.2.2	Below Depot Maint Matl Ship(Int)
	304.1.2	Depot Maint Mat'l Air
	304.2.2	Depot Maint Mat'l Ship
	308.1.1	Aircraft Replenishment Spares
	308.2.1	Ship Replenishment Spares

Source: PRICE-based ARINC Cost Estimate

Table VI presents the cost element estimates for the ten significant elements previously identified. These estimates are presented on a case by case basis and cost differentials and percentage differentials are quantified.

a. Investment Cost Element Differentials

In Table VIII, Case III investment costs were determined to be $721.2 million (FY 79 dollars). This is $53.4 million greater, (or 8.00 percent more) than the investment costs of a Case I procurement. This added investment cost comprises 76.8 percent of the total relevant Case I to Case III difference of $69.5 million. From this, it is evident that the Investment category is the source of the greatest part of total case differences. A similar argument can be made for a Case I to Case II comparison where the investment differential is $42.9 million and the category comprises 83.46 percent of the gross differential.

The investment category differential can be traced in its entirety to the four investment cost elements identified in Table VII. The reason for this is that the ARINC model utilizes cost estimates for the element "RPU," (Cost Element 201.2.1), as an input for the cost equations by which estimates for the other three investment elements are derived. In other words, all four investment elements have estimating equations/relationships which are in some way linked to the cost element "RPU." Consequently, as the RPU

Table VIII

Significant Cost Element Estimates by Case

(Constant FY 79 $Millions)

COST ELEMENT NUMBER	COST ELEMENT	CASE I	CASE II	CASE III	Δ II-I	% II-I	Δ III-I	% III-I
201.2.1	RPU	$196.562	$225.738	$232.889	$29.176	14.84%	$36.327	18.48%
201.2.2.1	Sustain Eng.	15.663	17.122	17.479	1.459	9.31%	1.816	11.60%
202.4.3	Group B Set Spares	65.[illegible]83	71.910	73.412	6.127	9.31%	7.629	11.60%
[illegible]3.1	Sets	65.783	71.910	73.412	6.127	9.31%	7.629	11.60%
302.5.1.2	Below Depot Mnt Mat'l Air (INT)	1.879	2.282	2.273	.403	21.45%	.394	20.97%
302.5.2.2	Below Depot Mnt Mat'l Ship (INT)	.961	.969	1.344	.008	.83%	.383	39.85%
304.1.2	Depot Mnt Mat'l Air	26.849	33.274	33.117	6.425	23.93%	6.268	23.85%
304.2.2	Depot Mnt Mat'l Ship	14.599	14.755	20.698	.156	1.07%	6.099	41.78%
308.1.1	Acft Replen. Spares	5.531	6.543	6.526	1.012	18.30%	.995	17.99%
308.2.1	Ship Replen. Spares	3.235	3.241	4.192	.006	.19%	.957	29.58%
Total of Significant Elements		$396.845	$447.744	$465.342	$50.899	12.83%	$68.497	17.26%
Total Δ of all Cost Elements					$51.441		$69.548	
% Significant Δ / Total						98.95%		98.49%

costs increase with greater procurements of higher cost five-channel sets (Cases II and III), a corresponding rise in the cost estimates for "Sustaining Engineering," "Group B Set Spares" and "Sets" is experienced.

As an example, Sustaining Engineering, Cost Element 201.2.2.1, is computed as 5 percent of the sum of all the estimates subordinate to "Group B Kits"--Cost Elements 201.2.1 through 201.2.1.5.2 (refer to the CAIG format in Appendix B). Within that summation, the only cost which differs among alternatives is that for the RPU. Therefore the difference in sustaining engineering estimates among alternatives is simply a function of RPU cost differences. A similar RPU cost "flow-through" underlies the differences found between alternative estimates for both the "Group B Set Spares" and "Sets" cost elements.

(1) RPU Costs. To fully understand the investment differentials identified through the analysis of the ARINC model estimates, it is important to understand the computation of the RPU cost element. As discussed in Chapter IV, RPU estimates are a function of the RCA PRICE estimated first-unit-production-cost (FUPC), learning curve slope and the number of units produced. The PRICE model places the FUPC of a 2-channel RPU at $58,642 and that of a 5-channel RPU at $99,856. As alternative cases demand increased quantities of a given model RPU, the cost of that set is

reduced by learning curve effects. However, the decrease in average unit cost of the five-channel RPU never offsets the very significant initial difference ($41,214) between the high and medium dynamic receivers FUPC's.[2] The result is that total RPU expenditures increase with each case requiring increases in high-dynamic RPU's. The increases in Case II and III RPU costs are $29.2 million (FY 79 dollars) and $36.3 million, respectively, above the Case I RPU cost estimate. In the next chapter current FUPC estimates will be subjected to sensitivity analysis and the resulting differentials explored.

(2) Sustaining Engineering. Case III Sustaining Engineering costs yield a $1.82 million (FY 79 dollars) differential cost above the Case I assumption. As earlier discussed, this cost increase is solely the result of RPU cost estimate increases. It is unlikely that sustaining engineering, which is generally considered a cost required for product improvement and refinement, would increase in relation to the cost of RPU's. An argument could be made that reduction of RPU types from a mix of two

[2]The authors suggest that a reason for this high differential may be found in the apparent independence maintained by the model in its computation of the first unit production cost of each RPU. The authors feel that the result is a cost overestimation of those first units. This will be discussed in the following chapter.

and five-channel sets to the common five-channel buy would reduce sustaining engineering costs. A creditable explanation for this argument is that only one instead of two RPU types need be updated or improved.

(3) Group B Set Spares Cost. The Case III Group B Set Spares element reflects the costs associated with necessary spares for the user equipment. It is computed as 20 percent of the sum of the Group B Kit plus Sustaining Engineering cost elements and is budgeted for expenditure in the year of set procurement--two years prior to installation. Since the cost of other major system components do not vary among alternative cases, the "RPU" estimate can be identified as the source of this differential. Table X reveals that the Case III cost of this element is $7.63 million (FY 79 dollars) above the Case I cost (or 11.60 per cent greater). It is likely, assuming stockage requirements remain constant, that Group B Set Spares will reflect a relative cost rise with the Case II or III alternative since the RPU costs for the five-channel set exceeds two-channel RPU costs. In Chapter VII cost savings will be identified which result from lower stockage level requirements under a common RPU procurement.

(4) Sets Cost. The Sets element is computed exactly the same as Group B Set Spares but is budgeted in the year of set installation. This cost element at face value

represents an additional sparing of LRU's at 20 per cent of the cost of the sum of Group B Kits plus Sustaining engineering. However, discussion with the Navy program office reveals that the element is actually a means by which "management reserve" is budgeted. The estimated differentials among cases are exactly the same as those for Group B Set Spares cost element. Although a management reserve is necessary in most acquisitions, it is highly unlikely that the amount of this reserve need fluctuate with the RPU cost. Consequently the authors will later deduct this cost differential from the total Case II and III differentials previously quantified.

b. O&S Cost Element Differentials

Although there were thirteen elements which showed cost differentials within the O&S category, only the six elements identified in Table VII will be quantified. The common quality of these six cost elements is that they are in some way "hardware" related. Four of the six elements are repair "material" cost estimates while the last two are direct estimates for replacement of LRU's and SRU's which are either lost, destroyed or determined irreparable. These six elements combine to explain 21.7% of the total constant dollar differential which exists between Cases I and III.

(1) Intermediate Repair Materials Cost. Material costs at the intermediate maintenance level (Cost

Elements 302.5.1.2 and 302.5.2.2) increase directly as a function of relative quantity increases in the high dynamic RPU. Although these elements estimate material costs for repair of all user equipment components, once again the RPU is the only component which varies among alternatives. The increased cost for material (repair parts) can therefore be attributed to the following two RPU related factors.

First, the Case II and III procurements have relatively higher estimated RPU costs and thus higher costs for repair parts. The second factor is that the mean time between failure (MTBF) is significantly less for the five-channel system. The ARINC model utilizes MTBF rates for the high dynamic RPU of 2700 hours and for the medium dynamic receiver of 4761 hours. Therefore, as increased quantities of five-channel RPU's are substituted into two channel applications, more frequent failures occur and this results in increased material costs. However, it should be noted that these MTBF values are not validated, but rather were early design estimates. In fact RPU reliability and maintainability requirements are incorporated into two specifications for <u>system</u> wide Mean Time Between Maintenance (MTBM). These specifications require a UE system, irrespective of model RPU incorporated, to meet a MTBM for ship systems of 1600 hours and for aircraft systems of 1000 hours [Ref. 32].

The 20-year costs for aircraft intermediate material costs is approximately $.394 million (FY 79 dollars), or 21.0 percent, greater than like costs for a Case I procurement. Likewise, the Case III estimate for ship intermediate material costs reflects an increase of $.383 million which is comparable to the aircraft material increase. However, since the cost increase is computed from a smaller initial Case I materials cost base, the percentage increase is greater at 39.81 percent.

(2) Depot Repair Material Cost. At the Depot maintenance level, repair material cost increases are incurred in both the aircraft (Cost Element 304.1.2) and ship (Cost Element 304.2.2) estimates as procurement Cases II or III are selected. The reasoning is the same as for the intermediate level material cost increases--more expensive material and more frequent failures. Table VIII displays the actual cost differentials among the alternatives.

(3) Replenishment Spares Cost. The Replenishment Spares Cost Elements, (308.1.1 and 308.2.1), reflect cost increases for Cases II and III simply as a function of RPU costs and the number of higher priced RPU's procured. Since five-channel receiver-processors cost more than the two-channel models, SRU's and LRU's procured to replace lost or irreparable parts or units cost more. Again the specific differentials can be found in Table VIII.

D. SUMMARY

Chapter V has utilized the ARINC Research Corporation ACBEN Cost Model, constrained by several assumptions, to estimate the investment and O&S costs associated with three procurement alternatives for GPS user equipment. The analysis indicated that receiver-processor costs for installed sets, i.e. excluding spares, were a major driver in the total costs of these alternatives--comprising 25.84 percent of the total Case I relevant cost. Therefore, as alternative cases demanded increased quantitites of the higher cost, five-channel RPU's, cost differentials between the alternatives increased in a direct relation.

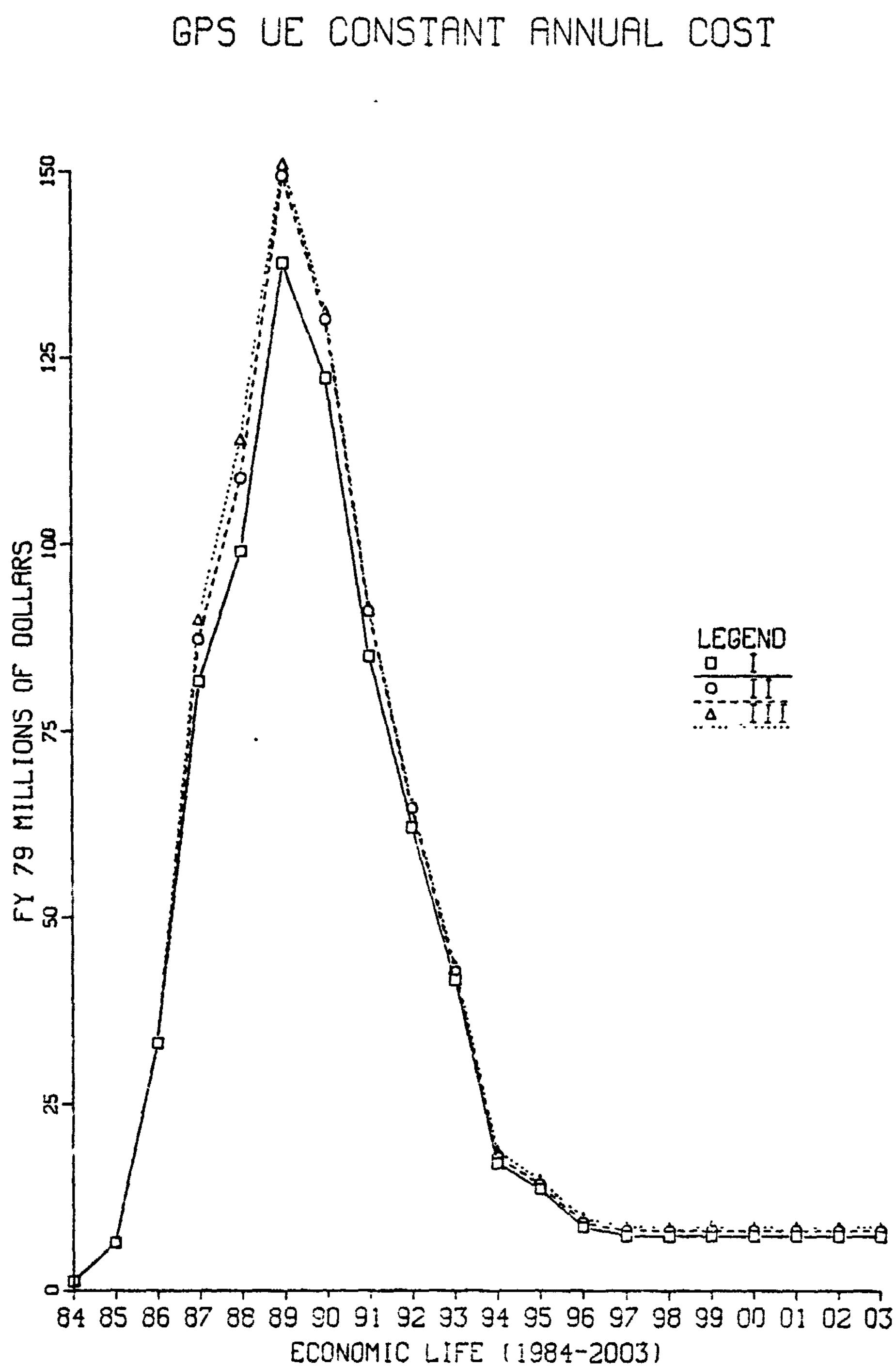
Cost differentials were then quantified, first on an aggregated level. Further analysis of the cost differentials, on a cost category basis, revealed that the majority, (in excess of 75 percent), of the cost increase associated with a Case II or III procurement was resultant from increased investment costs.

Analyzing the data on a cost element basis revealed the large investment differentials could be explained in total by the cost estimate changes in the "RPU" cost element. As Case II and III procurements required increased expenditures for greater quantities of five-channel RPU's, the other investment elements reflecting cost differentials increased in direct relation to the RPU cost increase. The approximate

$41,000 (FY 79 dollars) difference in two and five-channel first-unit-production-cost was identified as the major source contributing to the differentials among alternatives.

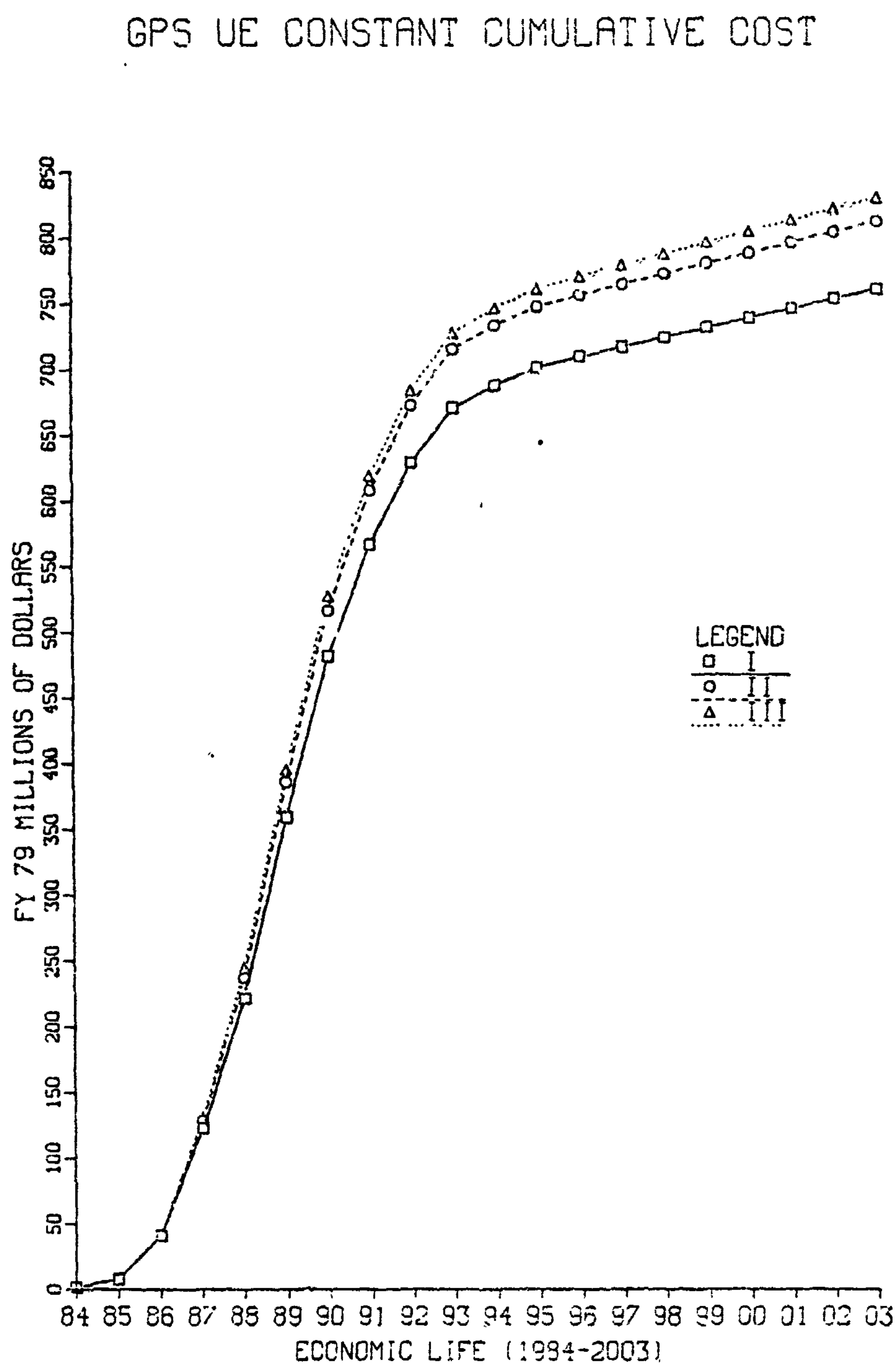
To a lesser degree receiver-processor costs impacted the O&S cost area. The six cost elements identified as the primary sources of O&S differential were all directly tied to material or hardware costs. Since other system components were unchanged in either quantity or cost among alternatives, the RPU cost increases could be identified as the major cause for the increasing O&S cost differentials experienced under the Case II and III assumptions.

Figures 5.5 and 5.6 provide a depiction of the estimated annual and cumulative cost flows for Navy GPS UE over the system's economic life. Review of these graphs show the strict dominance of Case I over either Cases II or III from a simple minimization of life cycle cost standpoint. Although UE costs were discounted, no change occurred in the relative dominance of Case I over II. Likewise Case II remained dominant over Case III. Figures 5.7 and 5.8 display the discounted estimates for annual and cumulative costs for the three alternative procurements.



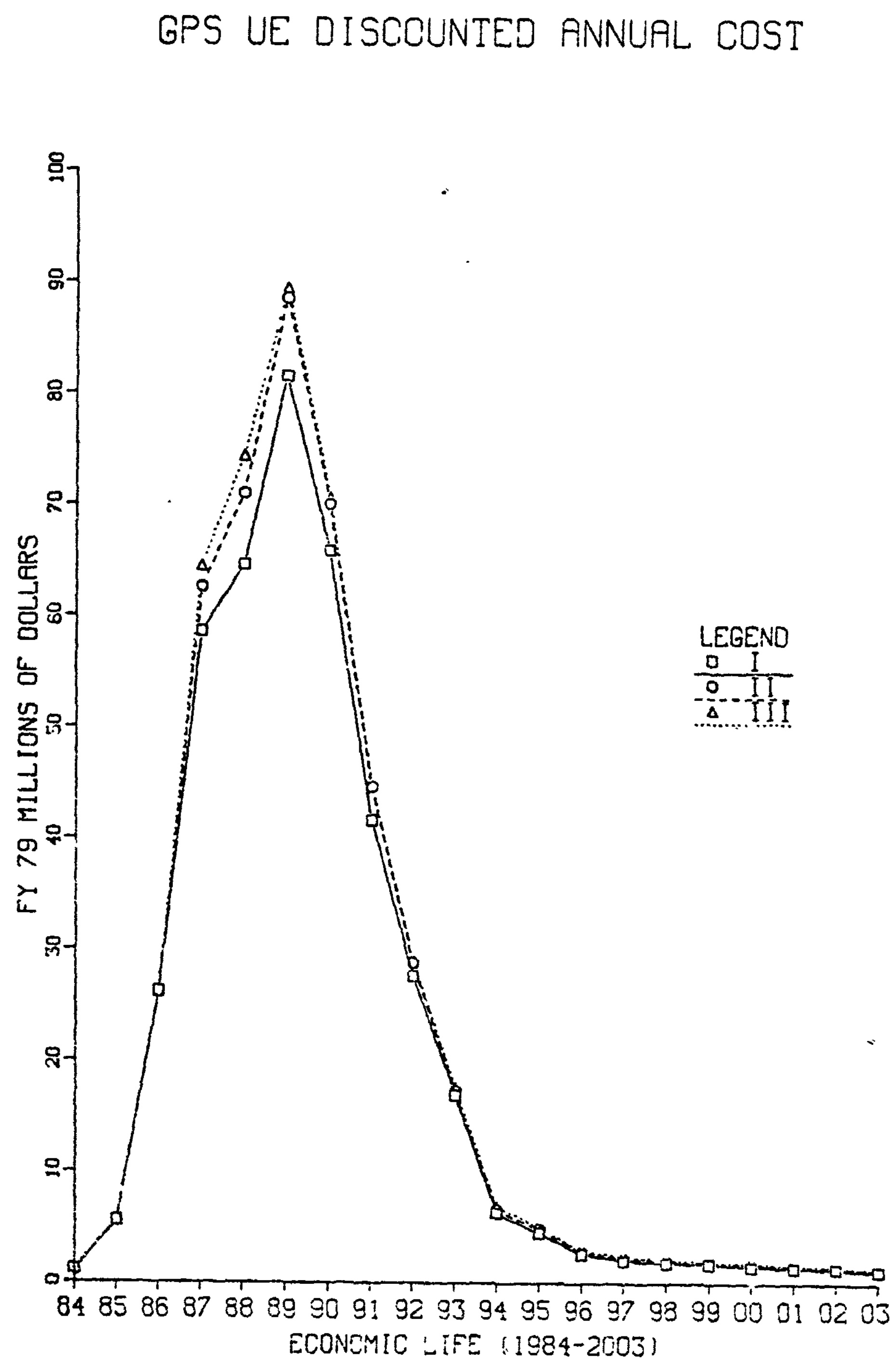
Source: PRICE-Based ARINC Cost Estimate

Figure 5.5 Comparative Annual GPS UE Expenditures



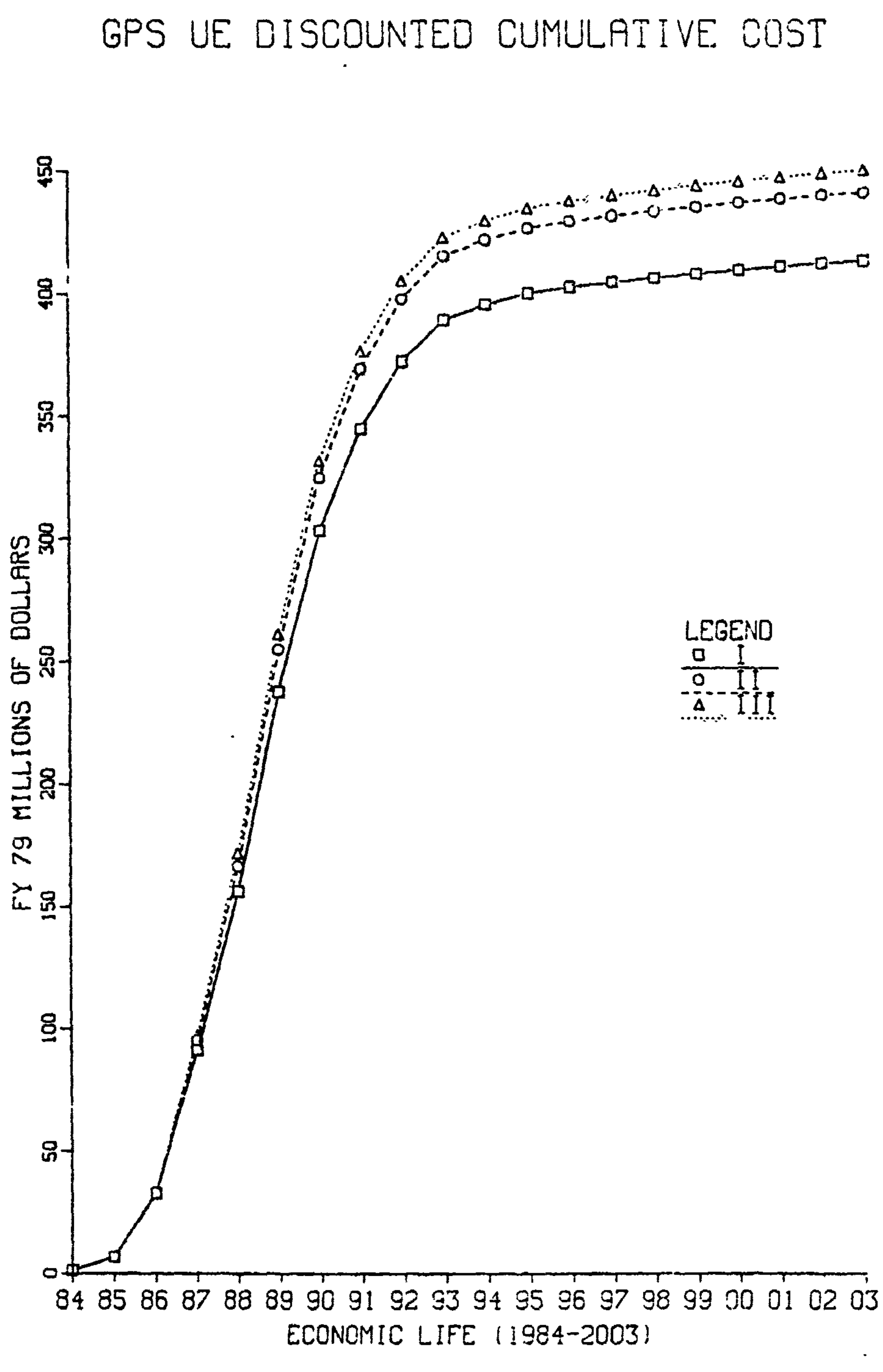
Source: PRICE-Based ARINC Cost Estimate

Figure 5.6 Comparative Cumulative GPS UE Expenditure



Source: PRICE-Based ARINC Cost Estimate

Figure 5.7 Discounted Comparative Annual Expenditures



Source: PRICE-Based ARINC Cost Estimate

Figure 5.8 Discounted Comparative Cumulative Expenditures

VI. SENSITIVITY ANALYSIS

The discussion in Chapter III, in part, addressed the importance of sensitivity analysis in a LCC study. It is particularly important that decision makers reviewing such analyses be aware of those model assumptions and cost estimating relationships which, if in error, might have a major impact on a study's overall conclusions and recommendations.

The analysis in Chapter V repeatedly identified the pervasive influence that the RPU cost estimate had upon total cost differentials among the three procurement alternatives. At a more basic level it was shown that there was a direct relation between the cases' total cost differentials and the first unit production cost estimates for the RPU. In fact, the PRICE-estimated first unit production cost influenced, either directly or indirectly, every cost element which showed significant differentials between alternatives. Because of the major impact of the PRICE-estimated FUPC's upon total UE system costs, these first unit estimates will be the focal point of our sensitivity discussion.

A. FIRST UNIT PRODUCTION COST

The large cost differential ($41,214) between the medium and high dynamic RPU's first unit costs has been a concern among Navy program office personnel for some time. That concern evolved primarily from both intuition and experience

on the part of those personnel. Their preliminary analysis indicated it was illogical to expect that a five-channel RPU, (which utilized as much as 80 percent common components), would cost as much as 70 percent more than a somewhat simpler two-channel RPU. That insight may have been recently borne out by an independent cost analysis (ICA) completed jointly by the Air Force Space Division Comptroller and the Joint Program Office in October 1982 [Ref. 33].

The results of the Air Force study indicate that not only is the cost differential between two and five-channel RPU's much smaller than initially estimated, but that the narrowing of the FUPC's resulted in an approximate $24,000 cost decrease in the high dynamic RPU. The results of the ICA now place the cost of a medium dynamic RPU at $60,000 and the cost of a high dynamic RPU at $75,000 (FY 79 dollars). The PRICE and Air Force ICA first unit cost estimates are compared in Table IX below:

Table IX

First Unit Production Cost Comparison

(Constant FY 79 $thousands)

	RCA PRICE Estimate	A/F ICE Estimate	Percent Difference
2-channel (MD)	$58.6	$60.0	2.4%
5-channel (HD)	99.9	75.0	(24.9%)

Source: PRICE and ICA-based ARINC estimates

Because of the potential impact of these significant differences, the researchers had an additional LCC estimate computed by ARINC Research for each of the three procurement alternatives. However, the Air Force estimated first unit production costs were substituted into the ACBEN model for both the two and five-channel RPU. The results of this second set of estimates will be presented in a comparative format in the forthcoming sections of this chapter.

B. THE AIR FORCE INDEPENDENT COST ANALYSIS

In the ICA-based cost estimate, all previous (Chapter V) assumptions and restrictions remained constant. Quantities and schedules remained the same as those provided in Tables IV and V, and the cases for which costs were estimated were synonymous with the case definitions of the initial estimate, i.e. Case I was still the baseline and Case III was an all five-channel procurement, etc. The only difference in the computation of the new set of estimates was in the use of different first unit production costs.

The presentation of these costs are in a format similar to that of the original estimate. The costs are presented on a total cost category and cost element basis for each case under review. The estimates are then compared to determine the cost differential between each case. Finally, the alternative case cost differentials from the new estimate are

compared with those differentials quantified in the initial estimate.

The only difference in the format of this cost presentation from that in Chapter V is that discounted costs are not computed. Figures 5.6 and 5.8 indicated that no cost "crossover" occurred during the economic life of the analysis. Therefore, there exists no discount rate which will cause a switch in the least cost alternative.

C. TOTAL ALTERNATIVE COSTS

Table X presents a summary of economic cost data (constant FY 79 dollars) for Navy GPS user equipment. This cost data was derived utilizing the Air Force estimated first unit production costs. The costs are aggregated by the three major cost categories discussed in Chapter III. As in the

Table X

ICA Estimated Costs by Case and Category

(Constant FY 79 $Millions)

		Case I	Case II	Case III
RDT&E	(1XX)	$125.9	$125.9	$125.9
Investment	(2XX)	625.2	638.5	643.0
O&S	(3XX)	87.3	91.6	95.4
Total (Less Sunk Costs)		(125.9)	(125.9)	(125.9)
Total Relevant Cost		$712.5	$730.1	$738.4

Source: ICA-based ARINC cost estimate

Chapter V discussion, RDT&E costs are presented for reader information. They are, however, considered irrelevant and are later subtracted to provide a total relevant cost.

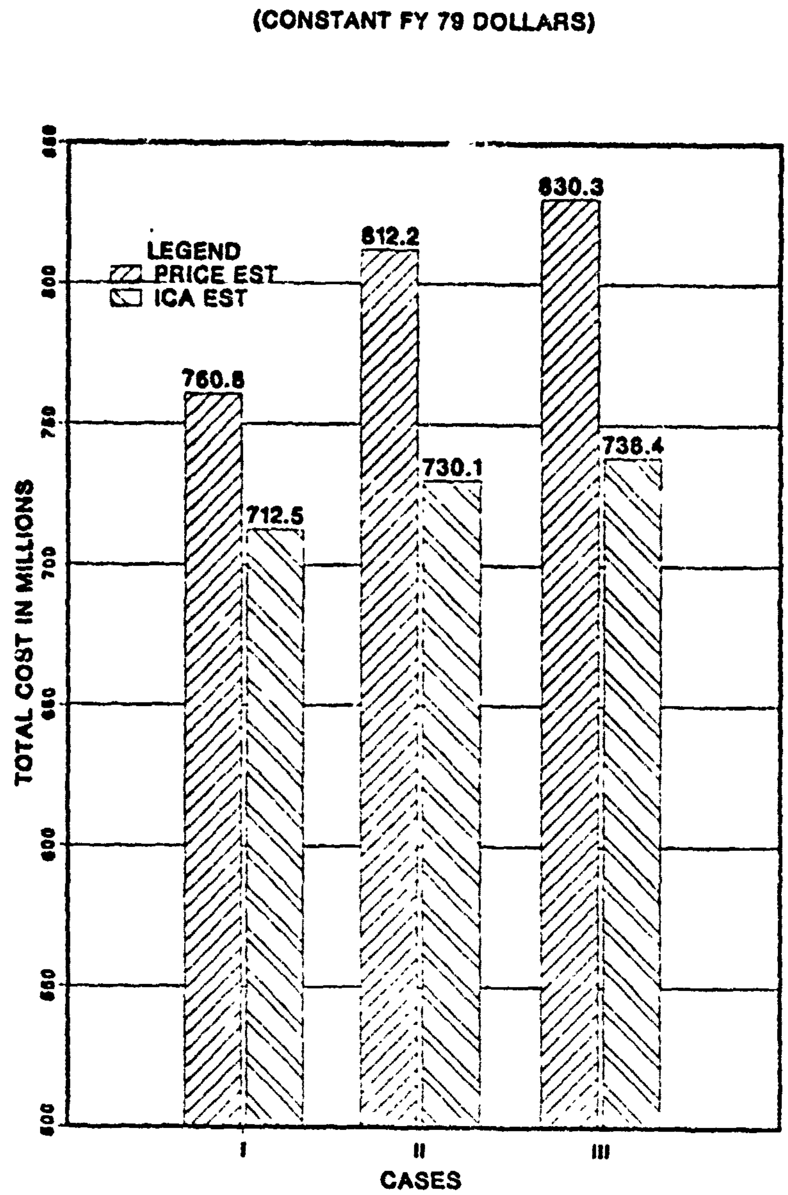
Figure 6.1 presents a comparative bar chart depiction of the total costs of each alternative procurement under both the PRICE and ICA first unit cost estimates. It provides an indication of the relative cost differences resultant from the use of the lower ICA FUPC estimates. The reduction in total expenditures for Case I, II and III procurements from their similar PRICE estimated totals are $48.3 million, $82.1 million, and $91.9 million (FY 79 dollars), respectively.

D. ALTERNATIVE COSTS BY CATEGORY

Table X displayed the ICA estimates for individual cost categories. Figure 6.2 is a bar chart depiction of the contribution to total cost by the investment and O&S cost categories. Comparison of this figure with Figure 5.3 reveals that no significant change occurred from the original estimate in the relative contribution of each category to total cost.

E. ALTERNATIVE COSTS BY RELEVANT COST ELEMENTS

The same four investment and six O&S cost elements utilized in Chapter V to describe cost differentials are again used in this discussion. However, because of the relative decrease in the magnitude of material costs,



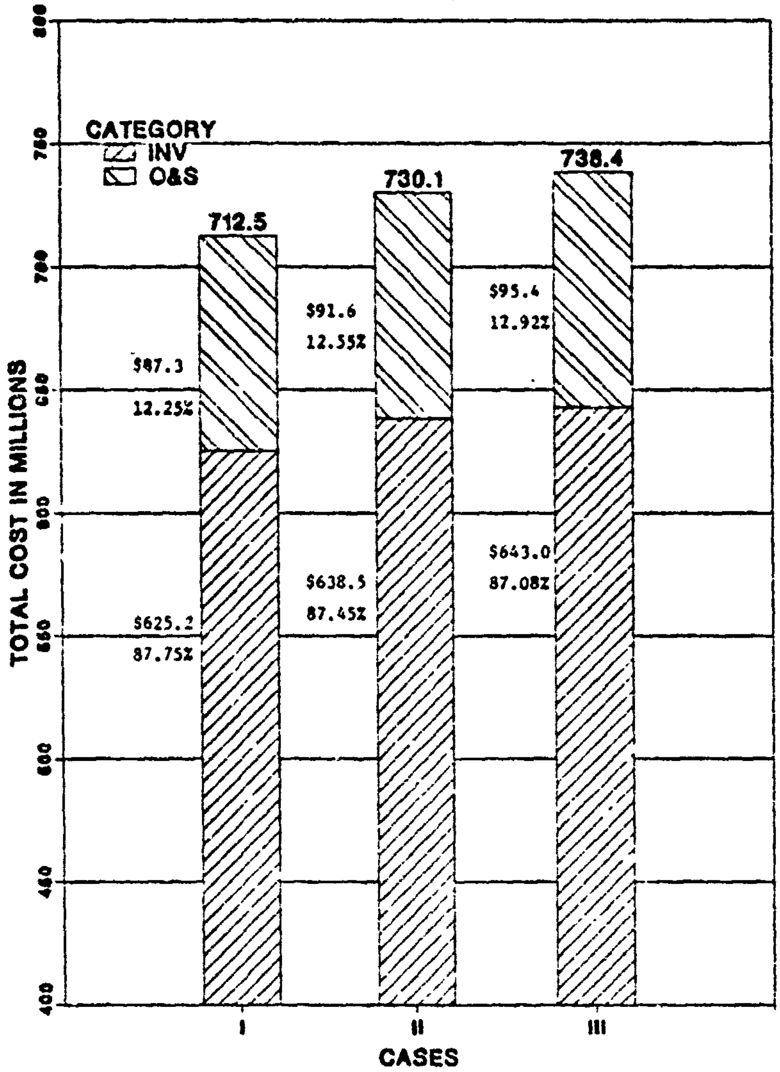
Source: PRICE and ICA-Based ARINC Estimates

Figure 6.1 Cost Comparison of GPS UE Total Cost Estimates

resulant from the FUPC decrease, the selected cost elements describe slightly less of the total differential--95.99

percent explained in this estimate as compared to 98.49 percent in the initial estimate.

(CONSTANT FY 79 DOLLARS)



Source: ICA-Based ARINC Cost Estimate

Figure 6.2 Alternative Costs by Category

The estimated case cost differentials as explained by the ten selected cost elements are summarized in Table XI below.

The table presents the estimated total cost differential and the percentage of that differential explained by each cost element.

Table XI

Case Cost Differential Analysis

(Constant FY 79 $millions)

Case Comparisons	II-I / % of Total	III-I / % of Total
Total Differential	$17.57 / 100.00%	$25.88 / 100.00%
Cost Elements		
Investment		
RPU	$ 9.05 / 51.51%	$12.14 / 46.91%
Sust. Eng	.45 / 2.56	.61 / 2.36
Gp B Set Sp	1.90 / 10.81	2.55 / 9.85
Sets	1.90 / 10.81	2.55 / 9.85
O&S		
Below Depot Mnt Mat'l Air	$ .19 / 1.08%	$ .19 / .73%
Below Depot Mnt Mat'l Ship	.01 / .06	.18 / .70
Depot Mnt Mat'l Air	2.73 / 15.54	2.73 / 10.55
Depot Mnt Mat'l Ship	.18 / 1.02	2.68 / 10.36
Acft Repln Spares	.62 / 3.53	.62 / 2.40
Ship Repln Spares	.06 / .34	.59 / 2.28
Total Explained	$17.09 / 97.26%	$24.84 / 95.99%
Unexplained	.48 / 2.74	1.04 / 4.01
TOTAL	$17.57 / 100.00%	$25.88 / 100.00%

Source: ICA-Based ARINC Estimate

The data presented in Table XI indicate that the RPU cost estimate is again the most significant source of cost

differential among alternatives. It comprises approximately 50 percent of the cost increase resultant from the selection of either a Case II or III procurement. Those investment cost elements directly related to RPU costs (e.g. "Group B Set Spares" and "Sets") also constitute substantial percentages of the total differential. The investment differentials for a Case II procurement comprise $13.3 million (FY 79 dollars) or 75.70 percent of the total differential associated with the alternatives. The differential explained by investment increases in a Case III procurement is $17.85 million or 68.98 percent of the total difference.

The O&S differentials indicate that "Depot Level Maintenance Materials," for both aircraft and ship units, constitute substantial percentages of the total case differences. The O&S estimates comprise $3.79 million or 21.57 percent of the total Case II cost difference and $6.99 million or 27.01 percent of the Case III differential.

F. SUMMARY

This analysis indicated that user equipment LCC is very sensitive to changes in FUPC. The 24.9 percent reduction in the high dynamic RPU's first unit cost resulted in decreases in total UE LCC of between $48.6 million and $91.9 million (FY 79 dollars). For Cases I through III these reductions equaled cost decreases, as a percentage of the initial PRICE-

based estimates, of 6.35, 10.11 and 11.07 percent, respectively. It is noteworthy that under the estimate provided by the ICA FUPC's, the Case III procurement alternative costs $22.4 million less than did a Case I procurement under the PRICE-based estimate.

The forthcoming chapter will utilize both the PRICE and ICA-based estimates as cost foundations from which quantified benefits will be deducted.

VII. COST-REDUCTION AND BENEFIT ANALYSIS

To this point in the discussion the focus has been two-fold: (1) to accurately determine life cycle cost estimates for the three procurement alternatives under consideration, and (2) to present the data in a comparative format emphasizing the differential dollar amounts among the three procurement cases.

It has been shown that selection of a procurement alternative other than the baseline alternative (Case I) could increase costs between 17.6 and 69.5 million dollars. These costs are, of course, dependent upon the alternative selected and the chosen estimate the decision maker utilizes for the first unit production cost for receiver-processor units. The acceptance of such increased costs should logically be offset by the value added of any benefits or cost adjustments which accrue from the selection of a particular alternative.

The objective of this section of the analysis is to determine and define possible benefits and cost adjustments relevant to the hypothesized procurement alternatives proposed in this study.

A. METHODOLOGY OF ANALYSIS

As mentioned, two major areas of possible cost reduction are explored. They are cost adjustments that are related to cost estimating model inadequacies, and benefits that are associated with specific alternatives. Only cost adjustments that can be substantiated with logical justification are discussed. In the case of benefits the procedure was to rank them and their supportive data, in order of significance either as a function of possible cost reduction, or system effectiveness improvement.

Those areas of the analysis which represent quantifiable savings are presented in a tabular format to arrive at "adjusted" total case differentials. Then, the analytical areas which have not been objectively quantified will be listed and discussed so that the reader can make his own determination of the probability that either savings or performance improvements will result.

B. COST REDUCTION FROM MODEL INADEQUACY

Several cost model shortcomings were briefly discussed in Chapter V. The inadequacies were associated with two investment cost elements. In the opinion of the authors, they resulted in the overstatement of both total case costs and the net differentials among alternative cases. In the following sections these model discrepancies will be discussed and the resulting cost estimate errors will be

quantified. After that discussion and quantification, the associated differentials will be adjusted for the possible overstatement of costs.

1. Sustained Engineering Cost

Sustained Engineering Cost is defined in one ARINC Research document as[Ref. 34]:

> "...the cost of retaining the GPS user equipment contractor for production engineering support. This support includes engineering changes, documentation changes, and system engineering support of platform modifications. The cost is allotted as 5 percent of the Group B Kit Cost (Cost Element 201.2.1)."

This cost equation produces an estimate of sustained engineering cost which is directly variable with the magnitude of installed user equipment hardware cost.

The cost equation is insensitive to both the number of similar UE sets procured and to the number of like vehicles within a host vehicle family. In one case, the sustained support provided to a generic "host vehicle" will actually be applied to over 1300 like vehicles. Certainly, in the case of all host vehicles which have more than one unit in service, the cost of providing the necessary engineering support does not increase with each end user of the equipment. Most sustained engineering support will be provided to either a single type user set (either two or five-channel) and/or a single vehicle within each host vehicle family. The support provided will then be assimilated to all similar applications.

In addition, the cost equation also fails to allow for the very likely sustained engineering cost reduction resultant from procuring only one model receiver-processor (the five-channel, Case III procurement) instead of RPU mixes as proposed in Cases I and II. Case III improves upon a Navy UE system already very high in commonality. This improvement should be reflected by a decreased demand for continued engineering support as it relates to the installed user equipment.

For these reasons the authors have reduced the differentials associated with this cost element from the total differences experienced under both the PRICE and ICA-based estimates. Refer to the Sustained Engineering lines in Table VIII (p.102) and XI (p.116) for the estimates upon which these reductions are based. Table XII reflects the adjustment of these case cost differentials.

2. Sets

The "Sets" cost element was previously introduced as a means by which the Navy Program Office budgeted for management or contingency reserves. It is, in addition, a means by which allowances are made for user equipment sparing uncertainties. With new technology equipments actual sparing levels cannot be based on empirical data. Consequently, budget estimates prepared for initial sparing levels are sometimes quite liberal. Since the production prototype GPS

Table XII

Differential Cost Adjustments

(Constant FY 79 $millions)

PRICE-Based Estimate

	Case II-I	Case III-I
Total Difference between Cases	$51.4	$69.5
Less Disallowed Differences		
Sustain. Eng	(1.5)	(1.8)
Sets	(6.1)	(7.6)
Total Relevant Differential	$43.8 (5.76%)*	$60.1 (7.90%)*

ICA-Based Estimate

	Case II-I	Case III-I
Total Difference between Cases	$17.6	$25.9
Less Disallowed Differences		
Sustain. Eng	(.4)	(.6)
Sets	(1.9)	(2.6)
Total Relevant Differential	$15.3 (2.15%)*	$22.7 (3.19%)*

* Numbers in parens indicate per cent of Case I total cost.

Source: ARINC Estimates and Authors' Analysis

UE has not yet been operationally tested, substantial uncertainty exists concerning both reliability and maintainability--each of which impact the determination of sparing requirements. Quantification of these performance

parameters in an operational environment is necessary before final sparing and logistics decisions can be made.

Nonetheless, it is unlikely that the reserve provided by the "Sets" cost element need function as a variable cost, increasing in proportion to the total RPU cost expenditures. Once again, Table VIII (p. 102) and XI (p. 116) provide the estimates upon which the reduction in the "Sets" cost element are based. Table XII reflects the adjustment of total case cost differentials from this reduction.

C. BENEFIT ANALYSIS

The determination of value or benefit from alternatives is a difficult process. Ideally all output measures should be quantifiable, or at least comparative by means of an acceptable common denominator. Unfortunately, real life situations do not always lend themselves to such parameters. Inasmuch as this is the case, the tack of the analyst is complicated by subjective inference in benefit determination.

GPS resides within this category. Considerable difficulty was experienced in acquiring sufficient detailed and precise performance and cost data in some areas, to allow quantitative evaluation of benefits applicable to the procurement alternatives. Perhaps, this is because the acquisition program is not yet in the IOT&E Phase of development. User equipment prototypes are still in the construction phase and thus have not been operationally

tested. Until such data are available, value added to proposed benefits assumes a degree of uncertainty. The following benefits introduced into discussion by the researchers are not intended to be either all encompassing or biased in selection, but are rather intended to be logical progressions of earlier study and analysis. As mentioned, benefits will be listed in a hierarchy of importance as to possible magnitude of cost adjustment and/or system performance improvement. This hierarchy is based solely on the opinions of the authors.

1. Interoperability

The progression of acquisition alternatives from Case I to III provides incremental improvements in GPS UE interoperability among Navy host vehicles. For example, the five-channel RPU procurements provided by both Cases II and III would ensure that any carrier-suitable aircraft would have a ready RPU spare only as distant as the aircraft next to it. Although somewhat diminished in importance by the very high designed mean time between failures, empirical data on operational availability frequently fail to substantiate these high designed reliability rates in new equipment. The result is that the logistic support system which has been provisioned for support of a high reliability system, is overwhelmed by operational demands. It is then that interoperability yields its greatest benefits.

2. Graceful Degradation

The term "graceful degradation" is often construed to mean a degraded but not nil operational capability when equipment failures occur. The design of the high dynamic RPU, although not required by specification, has evolved to provide such a capability. Under certain types of malfunctions associated with one or more of the RPU's receiver channels, the high dynamic set will continue to provide accurate navigational fixes--albeit somewhat degraded in precision. The medium dynamic set provides no such capability, failing after the loss of a single receiver channel.

Therefore, as high dynamic sets are favored in Cases II and III, there exists a potential for greater numbers of satisfactory mission completions as a direct result of this navigational enhancement.

3. Performance Differences

Several performance differences exist between the medium and high dynamic receiver-processors. These differences equate to performance improvements for the five-channel set and are relevant, in particular, to its application in aircraft.

The specification "Time to First Fix" (TTFF) is defined as the elapsed time from initial demand on a GPS set that has been turned on (for a minimum of seven minutes), to

the subsequent output and display of accurate position, time and velocity. The high dynamic set is designed to provide a TTFF of two minutes, which is half the time required for the two-channel system to meet this specification. This feature is important for aircraft alert launches and tactical situations requiring precision navigation, e.g. in a submarine threat scenario.

In addition to a more rapid navigational response, certain other technical improvements exist in the five-channel RPU. They include enhanced evaluation of several vehicular velocity measurements which combine to provide improved navigational accuracies.

D. SINGLE MODEL PROCUREMENT BENEFITS

Two generic areas were identified early in the program's development as principal risks for cost control. They were logistics and support and configuration control [Ref. 35]. The researchers feel that significant potential exists for cost reductions in these areas if a single model RPU procurement is pursued. In order for these savings to occur, it is necessary to eliminate the medium dynamic RPU from the procurement alternatives. Only a Case III procurement satisfies this condition, providing a common high dynamic RPU for all host vehicles. The following discussion hypothesizes a treatment of these cost reduction areas constrained by selection of the Case III alternative.

1. <u>Logistics and Support</u>

Logistics and Support encompasses many functional areas. One such area that may provide the greatest magnitude for possible cost reduction is RPU sparing. The existing minimum estimate for Case I RPU sparing is $39.3 million (FY 79 dollars).

Based upon discussions with Operations Analysts, the researchers feel there exist phenomena which allow for a one system UE sparing rate (the high dynamic RPU) of less than the combined rates for a procurement consisting of both medium and high dynamic receiver-processors. For any cost savings to accrue, this unit rate must be sufficiently reduced to offset the increased cost incurred by the high dynamic RPU selection. At this time, insufficient data are available to adequately model the comparative sparing requirements which could result from such an alternative.

In addition, the variable costs associated with supporting an additional LRU and its associated repair components (as required by Cases I and II), may be a significant source of cost reduction. Specifically they are: (a) the costs of carrying the additional LRU's and associated components in inventory, (b) costs of filling user orders, (c) stock out costs and, (d) the costs of operating the information processing system for the inventory. Admittedly, these costs are difficult to quantify at this stage of

program development, however they have an opportunity cost; i.e., should a Case III strategy be selected, those saved resources could be allocated to other areas within either the GPS program or the Navy.

2. Configuration Control

Maintaining configuration control of user equipment to preserve commonality has been a central issue within GPS development since program inception. The second major area in which potential system cost savings may reside is configuration management of the receiver-processor unit. The selection of a single model RPU as proposed by Case III would facilitate configuration control in both the areas of UE software and hardware.

a. Software

It has been estimated that a minimum of sixty percent of UE software resides within the RPU. Therefore, by reducing user equipment RPU model types within a procurement, as proposed by Case III, cost savings in RPU software maintenance as large as fifty percent could result. Exact allocation of software maintenance costs among the DOD users has not yet been determined. However, it is the authors' opinion that should the Navy elect the Case III procurement alternative, no charge for medium dynamic RPU software maintenance should be allocated to that service.

b. Hardware

Change is always necessary to enhance design attributes, to correct latent design deficiencies, to embrace new technology and to accomodate changing tactics and new threats. However, these changes in configuration must be carefully controlled. Selection of a Case III alternative facilitates the control procedure by effectively reducing the probable number of hardware changes in RPU configuration. In this same vein, those costs asociated with documentation and training could likewise be reduced.

E. SUMMARY

A central thrust of this chapter has been to quantify cost reductions resultant from model deficiencies. This effort identified between $2.3 million and $9.4 million (FY 79 dollars) in cost overstatements (Table XII). All cost differentials were then reduced by these estimating errors to obtain adjusted case differentials. These adjusted differences formed the backdrop before which several currently unquantifiable benefits were discussed. These benefits were ranked, in the opinion of the authors, by their potential for either cost savings or performance effectiveness improvement.

VIII. FINDINGS AND RECOMMENDATIONS

A. SUMMARY

In the preceeding analysis of both the PRICE and Air Force ICA-based user equipment estimates, it was shown that a quantifiable cost difference was incurred by a decision to procure UE under either the Case II or III alternatives. The size of that differential was reduced by those cost savings which were significant between alternatives.

Dependent upon the first unit production cost estimate utilized and procurement alternative selected, adjusted differences indicated that the selection of either of the two hypothesized procurements would require the additional expenditure of 15.3 to 60.1 million dollars over the system's 20-year life cycle. From another perspective it can be related that a Case II procurement, dependent upon the estimate used, could require as little as a 2.15 percent or as large as a 5.76 percent greater UE expenditure than the baseline case. Similarly, Case III estimates indicate a percentage increase totaling 3.19 percent for the recent ICA-based estimate or 7.90 percent under the PRICE-based estimate.

However, the decision maker should weight the total differentials among alternatives with some subjective evaluation of the possible savings and operational

enhancements which currently are unquantifiable. As the program matures through its operational test phases, many of the uncertainties which currently preclude the measurement of some cost savings will be resolved. Still other currently unquantifiable benefits, especially those related to system-wide effectiveness improvements may remain subjective. Nonetheless, they may prove to be valuable enhancements to the fleet operation and support of GPS user equipment.

B. GENERAL RECOMMENDATIONS

While this analysis is inconclusive in its support of either of the two hypothesized alternatives, it is the authors' belief that only an acquisition strategy based upon maximization of user equipment commonality can provide reduced life cycle cost. That maximization is only provided in a Case III procurement. It is recommended that the Navy actively engage in further analysis into those benefit areas which are currently unquantifiable, but whose substantiation is critical to the justification of a procurement alternative other than Case I. Specific recommendations for follow-on research are enumerated below.

C. SPECIFIC RECOMMENDATIONS

The recommendations which follow are in no way to be construed as the only areas which impact the determination of a cost effective Navy GPS procurement strategy. They are

listed in order of their relative importance as perceived by the authors. In the authors' opinion, any one of the recommended research areas may identify sufficient cost savings to offset the relatively small cost increases demanded from a Case III procurement.

- Effectiveness analysis should be conducted to determine the "value" derived from receiver-processor interoperability among all Navy aircraft (Case II) and also that derived from interoperability of all Navy platforms (Case III).
- Analysis should be conducted into the cost savings which should accrue within the logistics support system from a common RPU procurement. Potential areas of savings include inventory elimination of both the medium dynamic LRU and its unique SRU and bit-piece repair parts, software support, configuration control and the documentation of hardware, software, and maintenance publications.
- Closer scrutiny should be directed toward possible reduction in total spare requirements. The authors' discussion with operations analysts and their own experimentation with simplistic Poisson-based sparing models indicated the possibility for a reduction in the actual number of units required for sparing.

- Further analysis should be undertaken to ascertain the exact graceful degredation characteristics which apparently exist in the high dynamic RPU. Some determination should be made of the acceptability of the navigational accuracies provided by a system operating in a degraded mode.
- Although admittedly outside the original scope and assumptions placed upon this thesis, a program-level analysis should be undertaken to determine the benefits which might accrue to DOD if the Case III alternative was implemented by all services. Although segregated for purposes of this analysis, the Navy's procurement of user equipment is highly dependent upon tri-service program decisions and this fact cannot be ignored in the final analysis. Areas where program cost savings might occur are in the further extension of the learning curve upon high dynamic RPU costs, reduction in contractor production start-up costs and reduced documentation and configuration control costs. Areas which may offset these potential benefits include increased size, weight and cost associated with the five-channel procurement and installation.

D. CONCLUSION

This thesis has shown that the hypothesized GPS user equipment procurement alternatives are not, from a

performance-cost tradeoff standpoint, conclusively superior to the current proposal. Nonetheless quantified cost differentials are sufficiently small that both alternatives warrant further analysis. Case III differentials, dependent upon the FUPC estimate utilized, indicate that relatively small (3-8 percent) expenditure increases are required to field a system of maximum commonality. This high commonality, after further analysis, may provide logistics and support cost savings which outweigh the initial cost increases required for a Case III procurement. The result of a failure to further quantify these possible savings may be the Navy selection of a system which does not yield minimum life cycle cost.

APPENDIX A

Research and development

- User set development
- Platform integration
- Documentation

Investment

- Platform modification
- User sets
- Sustaining engineering
- Installation
- Support equipment
- Training equipment
- Initial spares

Operations and support

- Organizational and intermediate maintenance
- Depot maintenance
- Personnel support/training
- Replenishment spares

APPENDIX B

YEARLY COST FOR EQUIPMENT TYPE
DECISION PACKAGE POM-84 FY 79 K$

		1983	1984	1985	1986	1987
INSTALLATION SCHEDULE		0	0	0	0	0
100.	RDT&E					
101.	INTEGRATION					
101.1	VEHICLE MOD	0.000	308.000	1901.000	1312.000	0.000
101.2	TRAINER MOD	0.000	0.000	0.000	0.000	0.000
101.3	GROUP B MOD	0.000	0.000	0.000	0.000	0.000
102.	GP B DEVELOPMENT	0.000	232.500	0.000	0.000	0.000
200.	INVESTMENT					
201.1	GROUP A KIT					
201.1.1	VEH MOD	0.000	0.000	0.000	0.000	0.000
201.1.2	TRAIN MOD	0.000	0.000	0.000	0.000	0.000
201.1.3	GP B MOD	0.000	0.000	0.000	0.000	0.000
201.2	GROUP B KIT					
201.2.1	GROUP B KITS					
201.2.1.1	RPU	0.000	0.000	0.000	0.000	431.725
201.2.1.2	MOUNT/CAB	0.000	0.000	0.000	0.000	15.786
201.2.1.3	FMI					
201.2.1.3.1	ANALOG FMI	0.000	0.000	0.000	0.000	147.569
201.2.1.3.2	TEST FMI	0.000	0.000	0.000	0.000	0.000
201.2.1.4	ANTENNA					
201.2.1.4.1	FRPA	0.000	0.000	0.000	0.000	0.000
201.2.1.4.2	CRPA	0.000	0.000	0.000	0.000	55.169
201.2.1.5	CDU					
201.2.1.5.1	COMMON CDU	0.000	0.000	0.000	0.000	42.314
201.2.1.5.2	PECULIAR CDU	0.000	0.000	0.000	0.000	0.000
201.2.2	OTHER					
201.2.2.1	SUSTAIN ENG	0.000	0.000	0.000	0.000	34.628
201.3	INSTALLATION					
201.3.1	INSTALL LABOR					
201.3.1.1	VEH MOD LAB	0.000	0.000	0.000	0.000	0.000
201.3.1.2	TRAINER MOD LAB	0.000	0.000	0.000	0.000	0.000
201.3.1.3	GROUP B MOD LAB	0.000	0.000	0.000	0.000	0.000
201.3.2	INSTALL MATERIAL	0.000	0.000	0.000	0.000	0.000
202.	SUPPORT INVEST					
202.1	SUPPORT EQUIP					
202.1.1	PECULIAR SE	0.000	0.000	0.000	0.000	2074.000
202.1.2	COMMON SE	0.000	0.000	0.000	0.000	868.000
202.2	TRAINING EQUIP					
202.2.1	MTS	0.000	0.000	0.000	0.000	0.000
202.3	DOCUMENTATION					
202.3.1	VEH GP A DOC	0.000	0.000	0.000	0.000	0.000
202.3.2	MTS/TRN/SE DOC	0.000	0.000	0.000	0.000	0.000
202.3.3	GP B MOD DOC	0.000	0.000	0.000	0.000	0.000
202.3.4	GP B SET DOC	0.000	0.000	419.330	0.000	0.000
202.4	INITIAL SPARES					
202.4.1	VEH GP A SPARES	0.000	0.000	0.000	0.000	0.000
202.4.2	GP B MOD SPARES	0.000	0.000	0.000	0.000	0.000
202.4.3	GP B SET SPARES	0.000	0.000	0.000	0.000	145.438

YEARLY COST FOR EQUIPMENT TYPE
DECISION PACKAGE POM-84 FY 79 K$

		1983	1984	1985	1986	1987
202.4.4	TRAIN/MTS/SE SP					
202.4.4.1	TRAIN MOD SP	0.000	0.000	0.000	0.000	0.000
202.4.4.2	MTS SPARES	0.000	0.000	0.000	0.000	0.000
202.4.4.3	SUP EQUIP SPARES					
202.4.4.3.1	PECULIAR SE SP	0.000	0.000	0.000	0.000	311.100
202.4.4.3.2	COMMON SE SP	0.000	0.030	0.000	0.000	36.456
203.1	SETS	0.000	0.000	0.000	0.000	0.000
R&D/INVEST TOTALS		0.000	540.500	2319.880	1312.000	4162.185
300.	OPRNS & SUPPORT					
302.	BELOW DEPOT MNT					
302.1	AIR MAINT MANPWR					
302.1.1	ORG LEVEL	0.000	0.000	0.000	0.000	0.000
302.1.2	INT LEVEL	0.000	0.000	0.000	0.000	0.000
302.3	SHP MAINT MANPWR					
302.3.1	ORG LEVEL	0.000	0.000	0.000	0.000	0.000
302.3.2	INT LEVEL	0.000	0.000	0.000	0.000	0.000
302.5	MAINT MATERIAL					
302.5.1	MAINT MAT AIR					
302.5.1.1	ORG LEVEL	0 000	0.000	0.000	0.000	0.000
302.5.1.2	INT LEVEL	0.000	0.000	0.000	0.000	0.000
302.5.2	MAINT MAT SHIP					
302.5.2.1	ORG LEVEL	0.000	0.000	0.000	0.000	0.000
302.5.2.2	INT LEVEL	0.000	0.000	0.000	0.000	0.000
304.	DEPOT MAINT					
304.1	AIRCRAFT					
304.1.1	MANPOWER	0.000	0.000	0.000	0.000	0.000
304.1.2	MATERIAL	0.000	0.000	0.000	0.000	0.000
304.2	SHIPS					
304.2.1	MANPOWER	0.000	0.000	0.000	0.000	0.000
304.2.2	MATERIAL	0.000	0.000	0.000	0.000	0.000
307.	PERS SUPT/TRNG					
307.1	AIRCRAFT UNITS					
307.1.1	INDIVIDL TRNG	0.000	0.000	0.000	0.000	0.000
307.2	SHIP UNITS					
307.2.1	INDIVIDL TRNG	0.000	0.000	0.000	0.000	0.000
308.	SUSTAIN INVEST					
308.1	AIRCRAFT UNITS					
308.1.1	REPLN SPARES	0.000	0.000	0.000	0.000	0.000
308.2	SHIP UNITS					
308.2.1	REPLN SPARES	0.000	0.000	0.000	0.000	0.000
O&S TOTALS		0.000	0.000	0.000	0.000	0.000

YEARLY COST FOR EQUIPMENT TYPE
DECISION PACKAGE POM-84 FY 79 K$

		1988	1989	1990	1991	1992
INSTALLATION SCHEDULE		0	16	64	87	30
100.	RDT&E					
101.	INTEGRATION					
101.1	VEHICLE MOD	0.000	0.000	0.000	0.000	0.000
101.2	TRAINER MOD	0.000	0.000	0.000	0.000	0.000
101.3	GROUP B MOD	0.000	0.000	0.000	0.000	0.000
102.	GP B DEVELOPMENT	0.000	0.000	0.000	0.000	0.000
200.	INVESTMENT					
201.1	GROUP A KIT					
201.1.1	VEH MOD	155.200	620.800	843.900	291.000	0.000
201.1.2	TRAIN MOD	0.000	0.000	0.000	0.000	0.000
201.1.3	GP B MOD	0.000	0.000	0.000	0.000	0.000
201.2	GROUP B KIT					
201.2.1	GROUP B KITS					
201.2.1.1	RPU	1640.714	2142.619	718.994	0.000	0.000
201.2.1.2	MOUNT/CAB	61.121	81.063	27.413	0.000	0.000
201.2.1.3	FMI					
201.2.1.3.1	ANALOG FMI	483.719	591.600	195.452	0.000	0.000
201.2.1.3.2	TEST FMI	0.000	0.000	0.000	0.000	0.000
201.2.1.4	ANTENNA					
201.2.1.4.1	FRPA	0.000	0.000	0.000	0.000	0.000
201.2.1.4.2	CRPA	209.511	275.599	93.396	0.000	0.000
201.2.1.5	CDU					
201.2.1.5.1	COMMON CDU	158.087	204.733	68.501	0.000	0.000
201.2.1.5.2	PECULIAR CDU	0.000	0.000	0.000	0.000	0.000
201.2.2	OTHER					
201.2.2.1	SUSTAIN ENG	127.658	164.781	55.188	0.000	0.000
201.3	INSTALLATION					
201.3.1	INSTALL LABOR					
201.3.1.1	VEH MOD LAB	0.000	288.299	615.278	601.208	191.483
201.3.1.2	TRAINER MOD LAB	0.000	0.000	0.000	0.000	0.000
201.3.1.3	GROUP B MOD LAB	0.000	0.000	0.000	0.000	0.000
201.3.2	INSTALL MATERIAL	0.000	0.000	0.000	0.000	0.000
202.	SUPPORT INVEST					
202.1	SUPPORT EQUIP					
202.1.1	PECULIAR SE	0.000	0.000	0.000	0.000	0.000
202.1.2	COMMON SE	0.000	0.000	0.000	0.000	0.000
202.2	TRAINING EQUIP					
202.2.1	MTS	0.000	0.000	0.000	0.000	0.000
202.3	DOCUMENTATION					
202.3.1	VEH GP A DOC	0.000	0.000	0.000	0.000	0.000
202.3.2	MTS/TRN/SE DOC	0.000	0.000	0.000	0.000	0.000
202.3.3	GP B MOD DOC	0.000	0.000	0.000	0.000	0.000
202.3.4	GP B SET DOC	0.000	0.000	0.000	0.000	0.000
202.4	INITIAL SPARES					
202.4.1	VEH GP A SPARES	10.864	43.456	59.073	20.370	0.000
202.4.2	GP B MOD SPARES	0.000	0.000	0.000	0.000	0.000
202.4.3	GP B SET SPARES	536.162	692.079	231.799	0.000	0.000

YEARLY COST FOR EQUIPMENT TYPE
DECISION PACKAGE POM-84 FY 79 K$

		1988	1989	1990	1991	1992
202.4.4	TRAIN/MTS/SE SP					
202.4.4.1	TRAIN MOD SP	0.000	0.000	0.000	0.000	0.000
202.4.4.2	MTS SPARES	0.000	0.000	0.000	0.000	0.000
202.4.4.3	SUP EQUIP SPARES					
202.4.4.3.1	PECULIAR SE SP	0.000	0.000	0.000	0.000	0.000
202.4.4.3.2	COMMON SE SP	0.000	0.000	0.000	0.000	0.000
203.1	SETS	0.000	145.438	536.162	692.079	231.739
R&D/INVEST	TOTALS	3383.036	5250.467	3445.146	1604.656	413.272
300.	OPRNS & SUPPORT					
302.	BELOW DEPOT MNT					
302.1	AIR MAINT MANPWR					
302.1.1	ORG LEVEL	0.000	.087	.433	.904	1.067
302.1.2	INT LEVEL	0.000	1.226	6.129	12.793	15.092
302.3	SHP MAINT MANPWR					
302.3.1	ORG LEVEL	0.000	0.000	0.000	0.000	0.000
302.3.2	INT LEVEL	0.000	0.000	0.000	0.000	0.000
302.5	MAINT MATERIAL					
302.5.1	MAINT MAT AIR					
302.5.1.1	ORG LEVEL	0.000	0.000	0.000	0.000	0.000
302.5.1.2	INT LEVEL	0.000	.419	2.044	4.215	4.945
302.5.2	MAINT MAT SHIP					
302.5.2.1	ORG LEVEL	0.000	0.000	0.000	0.000	0.000
302.5.2.2	INT LEVEL	0.000	0.000	0.000	0.000	0.000
304.	DEPOT MAINT					
304.1	AIRCRAFT					
304.1.1	MANPOWER	0.000	2.679	13.396	27.964	32.987
304.1.2	MATERIAL	0.000	6.951	33.864	69.772	81.818
304.2	SHIPS					
304.2.1	MANPOWER	0.000	0.000	0.000	0.000	0.000
304.2.2	MATERIAL	0.000	0.000	0.000	0.000	0.000
307.	PERS SUPT/TRNG					
307.1	AIRCRAFT UNITS					
307.1.1	INDIVIDL TRNG	0.000	0.000	3.888	13.608	27.216
307.2	SHIP UNITS					
307.2.1	INDIVIDL TRNG	0.000	0.000	0.000	0.000	0.000
308.	SUSTAIN INVEST					
308.1	AIRCRAFT UNITS					
308.1.1	REPLN SPARES	0.000	1.451	7.061	14.533	17.023
308.2	SHIP UNITS					
308.2.1	REPLN SPARES	0.000	0.000	0.000	0.000	0.000
O&S TOTALS		0.000	12.813	66.815	143.790	190.148

YEARLY COST FOR EQUIPMENT TYPE
DECISION PACKAGE POM-84

FY 79 K$

		1993	1994	1995	1996	TOTAL
INSTALLATION SCHEDULE		0	0	0	0	197
100.	RDT&E					
101.	INTEGRATION					
101.1	VEHICLE MOD	0.000	0.000	0.000	0.000	3521.000
101.2	TRAINER MOD	0.000	0.000	0.000	0.000	0.000
101.3	GROUP B MOD	0.000	0.000	0.000	0.000	0.000
102.	GP B DEVELOPMENT	0.500	0.000	0.000	0.000	232.500
200.	INVESTMENT					
201.1	GROUP A KIT					
201.1.1	VEH MOD	0.000	0.000	0.000	0.000	1910.900
201.1.2	TRAIN MOD	0.000	0.000	0.000	0.000	0.000
201.1.3	GP B MOD	0.000	0.000	0.000	0.000	0.000
201.2	GROUP B KIT					
201.2.1	GROUP B KITS					
201.2.1.1	RPU	0.000	0.000	0.000	0.000	4934.052
201.2.1.2	MOUNT/CAB	0.000	0.000	0.000	0.000	185.383
201.2.1.3	FMI					
201.2.1.3.1	ANALOG FMI	0.000	0.000	0.000	0.000	1418.341
201.2.1.3.2	TEST FMI	0.000	0.000	0.000	0.000	0.000
201.2.1.4	ANTENNA					
201.2.1.4.1	FRPA	0.000	0.000	0.000	0.000	0.000
201.2.1.4.2	CRPA	0.000	0.000	0.000	0.000	633.675
201.2.1.5	CDU					
201.2.1.5.1	COMMON CDU	0.000	0.000	0.000	0.000	473.635
201.2.1.5.2	PECULIAR CDU	0.000	0.000	0.000	0.000	0.000
201.2.2	OTHER					
201.2.2.1	SUSTAIN ENG	0.000	0.000	0.000	0.000	382.254
201.3	INSTALLATION					
201.3.1	INSTALL LABOR					
201.3.1.1	VEH MOD LAB	0.000	0.000	0.000	0.000	1686.268
201.3.1.2	TRAINER MOD LAB	0.000	0.000	0.000	0.000	0.000
201.3.1.3	GROUP B MOD LAB	0.000	0.000	0.000	0.000	0.000
201.3.2	INSTALL MATERIAL	0.000	0.000	0.000	0.000	0.000
202.	SUPPORT INVEST					
202.1	SUPPORT EQUIP					
202.1.1	PECULIAR SE	0.000	0.000	0.000	0.000	2074.000
202.1.2	COMMON SE	0.000	0.000	0.000	0.000	868.000
202.2	TRAINING EQUIP					
202.2.1	MTS	0.000	0.000	0.000	0.000	0.000
202.3	DOCUMENTATION					
202.3.1	VEH GP A DOC	0.000	0.000	0.000	0.000	0.000
202.3.2	MTS/TRN/SE DOC	0.000	0.000	0.000	0.000	0.000
202.3.3	GP B MOD DOC	0.000	0.000	0.000	0.000	0.000
202.3.4	GP B SET DOC	0.000	0.000	0.000	0.000	418.880
202.4	INITIAL SPARES					
202.4.1	VEH GP A SPARES	0.000	0.000	0.000	0.000	133.763
202.4.2	GP B MOD SPARES	0.000	0.000	0.000	0.000	0.000
202.4.3	GP B SET SPARES	0.000	0.000	0.000	0.000	1605.468

YEARLY COST FOR EQUIPMENT TYPE
DECISION PACKAGE PON-84

FY 79 K$

		1993	1994	1995	1996	TOTAL
202.4.4	TRAIN/MTS/SE SP					
202.4.4.1	TRAIN MOD SP	0.000	0.000	0.000	0.000	0.000
202.4.4.2	MTS SPARES	0.000	0.000	0.000	0.000	0.000
202.4.4.3	SUP EQUIP SPARES					
202.4.4.3.1	PECULIAR SE SP	0.000	0.000	0.000	0.000	311.100
202.4.4.3.2	COMMON SE SP	0.000	0.000	0.000	0.000	36.456
203.1	SETS	0.000	0.000	0.000	0.000	1605.463
R&D/INVEST TOTALS		0.000	0.000	0.000	0.000	22431.14
300.	OPRNS & SUPPORT					
302.	BELOW DEPOT MNT					
302.1	AIR MAINT MANPWR					
302.1.1	ORG LEVEL	1.067	1.067	1.067	1.067	6.753
302.1.2	INT LEVEL	15.092	15.092	15.092	15.092	95.605
302.3	SHP MAINT MANPWR					
302.3.1	ORG LEVEL	0.000	0.000	0.000	0.000	0.000
302.3.2	INT LEVEL	0.000	0.000	0.000	0.000	0.000
302.5	MAINT MATERIAL					
302.5.1	MAINT MAT AIR					
302.5.1.1	ORG LEVEL	0.000	0.000	0.000	0.000	0.000
302.5.1.2	INT LEVEL	4.935	4.932	4.932	4.932	31.355
302.5.2	MAINT MAT SHIP					
302.5.2.1	ORG LEVEL	0.000	0.000	0.000	0.000	0.000
302.5.2.2	INT LEVEL	0.000	0.000	0.000	0.000	0.000
304.	DEPOT MAINT					
304.1	AIRCRAFT					
304.1.1	MANPOWER	32.987	32.987	32.987	32.987	208.974
304.1.2	MATERIAL	81.622	81.578	81.578	81.578	513.762
304.2	SHIPS					
304.2.1	MANPOWER	0.000	0.000	0.000	0.000	0.000
304.2.2	MATERIAL	0.000	0.000	0.000	0.000	0.000
307.	PERS SUPT/TRNG					
307.1	AIRCRAFT UNITS					
307.1.1	INDIVIDL TRNG	33.048	33.048	33.048	33.048	176.904
307.2	SHIP UNITS					
307.2.1	INDIVIDL TRNG	0.000	0.000	0.000	0.000	0.000
308.	SUSTAIN INVEST					
308.1	AIRCRAFT UNITS					
308.1.1	REPLN SPARES	16.970	16.959	16.959	16.959	107.917
308.2	SHIP UNITS					
308.2.1	REPLN SPARES	0.000	0.000	0.000	0.000	0.000
O&S TOTALS		185.720	185.663	185.663	185.667	1146.275

APPENDIX C

1.0 INTRODUCTION

ARINC has expanded the CAIG/LMI Cost Element Structures (CES) for aircraft, land vehicle, and ship systems and modified them to accommodate, in one CES, all three types of vehicles and all three services. In its present form it is intended to be used to present cost estimates to develop, acquire, integrate, and support new subsystems for Air Force, Navy, and Army host vehicles. This attachment defines the major cost elements in the CES.

2.0 SCOPE

At the first level of indenture, cost elements in the 100 series apply to research, development, test, and evaluation. Within the 200 series, cost elements apply to system and support investment (acquisition) costs. Operating and support costs are included in the 300 series cost elements. This dictionary describes the cost elements within each of these series.

With few exceptions, each cost element is identifiable to specific host vehicles, such as the FB-111 or guided missile frigate (FFG). RDT&E Cost Element 103, Unassigned R&D Costs, is intended to accommodate those GPS user set

contractor costs that are not identifiable to specific applications. (See Cost Element 103, below).

3.0 COST ELEMENT DEFINITION

100 RDT&E - This series of cost elements, when aggregated at this level, corresponds to each service's RDT&E budget appropriation as described in DoD Budget Guidance Manual 7110-1-M. That manual describes the criteria to be used to distinguish that which should be funded with the RDT&E appropriation from that which should be funded with the procurement or operations and maintenance appropriations.

101 Flexible Modular Interface (FMI)/Software Development - The cost of development of hardware and software to integrate the GPS user sets into a specific, separately identifiable host vehicle such as the FB-111, DDG, or XM-1. This development engineering is to be performed by the GPS user set contractor(s). Ultimately, the hardware and software become part of the host vehicle Group B kit.

102 User Set Tailoring/Host Vehicle Modification - Costs of user set contractor support to integration agencies/contractors to assist in interface design and related development engineering. Also includes user set manufacturer sustained engineering support after delivery of sets to the Navy. Similar support of sets delivered to the Army and Air Force are treated as investment costs included in Cost Element 201.2.2.

103 Unassigned R&D Costs - Costs of user set contractor RDT&E activities that cannot be associated with specific, identifiable host vehicles. Such costs include user set contractor support for Combined Environment Reliability Testing (CERT), depot support equipment design, etc. For each service, individual cost sub-elements separately identify those shared user equipment contractor costs as well as other RDT&E activities separately funded by, and unique to, each individual service. Service-unique costs are for such activities as initial operational test and evaluation, clock development, travel and per diem, test range support, etc.

104 Integration Engineering - Costs for Navy vehicle integration design and engineering by integration agencies/contractors, such as aircraft manufacturers, shipyards, field engineering installation teams, air logistics centers, and aircraft maintenance, rework, modification agencies. All post-DSARC III integration engineering, prototyping and testing within the Navy is to be RDT&E funded in this cost element. Integration costs after DSAR III for Army and Air Force applications are investment costs. (See Cost Element 201.1.2).

200 Investment - Acquisition cost of the system/equipment and of the provision for its support in its employed environment. It is the sum of Cost Elements 201 (System Investment) and 202 (Support Investment). A variety

of budget appropriations are involved, including the operations and maintenance, procurement, and construction appropriations.

201 System Investment - Sailaway costs of ships, flyaway costs of aircraft, and driveaway costs of vehicles or their subsystem counterpart as used in the DoD Budget Guidance Manual 7110-1-M. (See Glossary). At this level of aggregation for modifications, this cost element includes the subordinate Cost Elements 201.1 (Group A engineering and kits), 201.2 (Group B engineering and kits) and 201.3 (modification labor and materials costs). It is these costs needed to provide a systems/equipment for use.

201.1 Group A - Cost of engineering and production/procurement of integration kits to prepare the intended host vehicle to accept the Navstar GPS user set (Group B).

201.1.1 Group A (Integration) Kits - Sum of the unit costs of the A kits for each separately identifiable vehicle F-111E, DDG, etc.). These are production/procurement costs for the commodities referred to as Group A kits needed to prepare ships, aircraft, and ground vehicles to accept the Navstar GPS user sets as produced by the user set contractor. Also includes the cost of any kits required to modify existing (previously procured non-GPS) Group B type

components and/or crew (operator) trainers. Group A kits may be composed of both expense and investment items.

201.1.2 Group A Integration Engineering - Modification engineering costs to integrate GPS user sets in each specifically identified vehicle (F-4G, CCV, M-113). Includes costs for prototyping and testing (other than DT&E/IOT&E). Includes Group A (integration) modification engineering costs for aircraft, vehicles, crew trainers, and existing Group B non-GPS components. Also pre-production engineering costs for maintenance training sets and PSE-single. (see Glossary). Navy host vehicle integration designs, prototyping, and testing are treated as development engineering costs (Cost Element 104).

201.2 Group B (GPS User Set) - Costs are for procurement of user sets (including vehicle peculiar FMI and CDU) from the user set manufacturer for the three services (201.2.1) and for his sustained engineering support for sets after delivery to the Army and Air Force (201.2.2). Sustained engineering support for Navy sets after delivery is considered continued development engineering and is included in Cost Element 102. Cost Element 201.2.2.1.2, Sustained Engineering Support - Ships/Boats, is retained, however, but for reference only.

201.3 Installation - All labor and on-site, non-kitted materials costs required to complete the modification.

201.3.1 Labor Cost - Includes the cost of contractor, intragovernmental, and/or service-organic labor to modify existing Group B type components and install the Group A, Group B, and the modified Group B type components in aircraft, ships/boats, and ground vehicles. Also included is the cost of labor required to modify crew/operator trainers. Intergovernmental and service-organic labor costs include costs of direct labor, other direct labor (process shops), operations overhead, and general and administrative burdens. Contractor labor costs are those based on the contract negotiated labor rates. Since governmental and contractor labor rates may be significantly different, further breakout of these cost elements may be required as modification planning becomes more detailed. More detailed cost elements may also be required to accommodate the various circumstances affecting labor costs such as modification during programmed depot maintenance vs. speed line/during ship Life Extension Programs (SLEP) vs. Field Electronics Installation Teams (FEIT), etc.

201.3.2 Materials - Sub-cost elements coincide with the installation labor elements described above, costs are for those expense type materials commonly referred to as bench/shop stock. Normal shop stock may be supplemented by such materials as sealants which may be peculiar to the modification but come in quantities which make it

uneconomical for packaging in individual modification kits. These material costs are a relatively small component of the total modification costs; therefore, it may not be useful to distinguish direct materials from indirect materials in separate cost sub-elements. For modifications performed on contract, these materials may be government furnished or contractor furnished. Whether the materials are a direct cost to the government (as in government furnished) or an indirect cost via the contract, the materials are a relevant modification cost and where possible should be separately identified.

202 Support Investment - As System Investment (Cost Element 201) provided a system/equipment ready for use, Support Investment (Cost Element 202) provides that support needed for its continued use once deployed. These costs are for initial purchases as distinguished from operating and support costs which provide for subsequent sustained support throughout the remaining life of the system/equipment. Except for a few cost elements for ship modification, procurement funds are used for all support investment.

202.1 Support Equipment - The initial procurement cost for end items of peculiar and common equipment and software for operating, testing, repairing, or otherwise supporting the GPS-equipped vehicle as well as its attendant support and training equipment. (For a distinction between common and

peculiar support equipment and between peculiar SE, single application and peculiar SE, multiple application (see glossary).

202.2 Training Equipment and Services - The cost of procurir· ·nd installing (if applicable) training equipment and sot ·. Only modification-relevant installation costs shoul· · ·cluded, such as if the installation and checkout of the trainer were contractual requirements attendant to its purchase. Normal uncrating and set-up by users would not be considered a reimbursable or relevant expense.

The cost of training services includes training initial operator, maintenance, and instructor personnel. It does not include the pay and allowances for trainees, but does include their travel and per diem expenses directly related to initial operator and maintenance training (See 307). Treatment of these latter cost differs from the CAIG/LMI guidelines, which treat travel and per diem for initial training as an O & S cost because these costs are O & M funded. ARINC prefers to recognize these as bona fide modification-relevant investment costs, since like the other support investment cost elements, the requirement is comparatively short-lived for a modification.

202.3 Documentation - Includes cost of initial acquisition, reproduction, and distribution of management, scientific, engineering, and logistics information (except

provisioning data, Cost Element 202.4), reports, and documentation contractually required for delivery from a contractor. For modifications, such as GPS, costs are for both group A and Group B-related data.

Group A-related data are unique to a particular, separately identified host vehicle. This data supports the integration before, during, and after the modification. Group A-related data costs are included in Cost Elements 202.3.1 (aircraft), 202.3.4 (ship/boat) and 202.3.5 (ground/vehicles).

Data to support modification of an existing Group B component (e.g., CDU) are also included (Cost Element 202.3.3) but is separately identified since this component modification, whether performed organically or contractually, usually will not be accomplished by either the integration (Group A) agency or the Group B (GPS) manufacturer. Usually the component (existing Group B) modification will require separate funding and management.

Some Group B data relate to LRUs that are common to some aircraft, ship/boat and ground applications. Other data, such as those related to FMIs, are peculiar to specific, separately identifiable host vehicles. Separate cost elements are provided in recognition of the different service cost sharing and funding arrangements that appertain.

Data costs will also accrue to support new maintenance trainers and new support equipment (Cost Element 202.3.2). While recognizing that different funding arrangements (i.e., vehicle-manager funds and GPS-manager funds) will apply within this cost element, more detailed cost sub-elements are not identified since the aggregated costs are not expected to be significant.

202.4 Initial spares - The costs of secondary spares (investment items) and repair parts (expense items) needed to support the modified vehicle/manpack during the initial period of operating service, normally not longer than two years after the first modification is completed). Cost sub-elements are provided for costs of initial spares for Group A (integration), Group B (GPS, including FMI/CDU), modified existing Group B component(s), trainers, and support equipment (peculiar and common). Provisioning data costs are within each sub-element.

202.5 Facilities (Non-Production) - The cost of construction, conversion or expansion of facilities required for operation and/or support of the GPS-modified vehicle/manpack or support equipment. This cost element includes such costs funded with the military construction appropriations or, if less than $50,000, the service's operation and maintenance appropriation. Ship/boat modification required to accommodate new GPS support

equipment, for example, should be included in Systems Investment (Cost Element 201). Includes facilities costs for depot maintenance and below depot maintenance as well as relevant costs for training facilities.

300 Operating and Support - The variable cost of operating and supporting GPS-modified vehicles and manpacks, including contractor support.

301 Deployed/Direct Unit Operations - The cost of deployed (deployable) unit non-maintenance manpower; petroleum, oils, and lubricants (POL); and personnel supplies and services.

301.1 Personnel/Operations - The costs of crews/operators, command/staff personnel, and temporary additional duty (TAD) (ships/boats only). Includes only those GPS-relevant costs for basic pay, quarters, subsistence, clothing allowances, incentive and special pay for personnel operating or supervising the operation of the GPS equipment. Other non-maintenance deployed manpower costs are included in Cost Element 301.4. Below depot maintenance manpower costs are in Cost Elements 302.1 through 302.4.

301.1.2.2 Temporary Additional Duty (TAD) - Costs associated with the temporary assignment of shipboard personnel away from the ship for training, administrative, or other purposes. It consists of transportation, lodging, mileage allowances, per diem, and incidental travel expenses.

301.2 Material (Operating) - Includes direct materials consumed in vehicle/manpack operation. Principally these are POL costs which, due to GPS-relevant improvement in navigational accuracy, may result in a negative number (savings). Below depot maintenance material is in Cost Element 302.5.

301.3 Security - The cost of paying personnel needed for unit equipment security-entry control, security alert teams, etc. Includes deployed manpower for cryptological, denial-of-access support, if required.

301.4 Other Deployed Manpower (Other than Direct/Deployed Operations and below Depot Maintenance) - The cost of paying all other personnel, except direct operating, security and maintenance, but including public information, social actions, finance, and other support personnel. (Not expected to be a GPS-relevant cost element).

301.5 Personnel Support - The cost of supplies, services, and equipment needed to support deployed unit personnel. Includes administrative supply items, travel expenses, expendable office machines and equipment, custodial services, and other variable personnel-oriented support costs incurred at the deployed unit level. Does not include such costs unique and identifiable to Below Depot Maintenance (Cost element 302.6), nor to such costs for Installation Support (Cost Element 30[illegible] and Personnel

Training and Support (Cost Elements 307.1.4, 307.2.4, and 307.3.4).

302 Below Depot Maintenance - The cost of manpower and material needed for maintenance of deployed unit aircraft, combat vehicles, manpacks, ordnance and ships/boats.

302.1, 302.2, 302.3, and 302.4 Below Depot Maintenance Manpower - Includes the cost of paying the personnel needed to meet below depot maintenance requirements (including contractor support) of the deployed unit. Included are personnel needed 1) to meet the maintenance demands of assigned aircraft, combat vehicles, manpacks, ships/boats and their related support equipment, precision measurement equipment, trainers/simulators; 2) to provide for maintenance supervision and control; and 3) to cover related administrative requirements. Includes basic pay, quarters, subsistence, clothing allowances, and incentive and special pays.

For the Air Force, includes organizational and intermediate levels of maintenance.

For the Army, includes organization, direct support, and general support manpower.

For the Navy, includes direct labor expended during afloat, or ashore by intermediate maintenance activities (IMA). Includes direct labor expended by tenders and repair ships.

302.5 Maintenance Material - The cost of purchasing material from the General and System Support Divisions of the stock fund or via local purchase. This includes only non-reparable expense items consumed in the repair process. Excludes reparables/rotatables procured from the stock fund, which are included in Cost Elements 308.1.1, 308.2.1, and 308.3.1.

For Air Force units, includes materials expended at organizational and intermediate levels of repair.

For Army units, includes materials expended at organization, direct support and general support levels.

For Navy units, includes materials expended on shipboard or by tenders/repair ships afloat or by intermediate maintenance activities (IMA) ashore.

302.6 Personnel Support - The cost of supplies, services and equipment needed to support below-depot maintenance personnel. Includes costs of administrative supply items, travel expenses, expendable office machines and equipment, custodial services, and other variable personnel-oriented support costs incurred by, and identifiable to, the maintenance activities below depot maintenance.

303 Installation Support - The variable cost of providing support for deployed unit personnel at the unit's support installation(s). Includes contractual support. no significant, GPS-relevant costs are anticipated.

303.1 Base Operating Support - The cost of installation personnel and material necessary to directly support the deployed unit. Includes food service retail supply, and motor pool operations. These personnel and material costs would no longer be incurred by the installation if the deployed unit was moved elsewhere.

303.2 Real Property Maintenance - The variable costs of non-acquisition related construction, maintenance and operation of real property facilities, and related management and engineering support work and services.

303.3 Personnel Support - The cost of supplies, services, and equipment needed to support installation support personnel. Includes administrative supply items, travel expenses, expendable office machines and equipment, custodial services, and other variable personnel-oriented support costs incurred at the installation(s).

304 Depot Maintenance - The cost of manpower and material needed to perform vehicle/manpack and associated component, support equipment, and trainer/simulator maintenance at DoD centralized repair depots (including contractual support) and contractor repair facilities. Includes the funded costs of direct labor, direct material, other direct costs, indirect labor and material, and applied overhead chargeable to job/work orders for overhaul, progressive/programmed depot maintenance, analytical rework,

modification, repair, inspection and test, manufacture, reclamation of vehicles, subsystems, components and associated support equipment and trainers/simulators. Cost of similar work accomplished via contract maintenance or interservice maintenance support is also included (See DoD 7220.29-H, Department of Defense Depot Maintenance and Maintenance Support Cost Accounting and Production Reporting Handbook). For GPS, each service will fund for depot maintenance of their own sets out of operations and maintenance appropriations to reimburse the Industrial Fund.

304.1 Aircraft and 304.3 Ground Applications Depot Maintenance Manpower - Cost Elements 304.1.1 and 304.3.1 - The cost of labor needed to perform major overhaul, repair, modification, inspection, and storage and disposal of aircraft, ships/boats, ground combat vehicles, associated components, support equipment, and trainers/simulators. Costs are based on Depot Product Standard Hours (DPSH), or equivalent, or anticipated/actual negotiated contract labor rates.

Material - Cost Elements 304.1.2 and 304.3.2 - The cost of material consumed in the depot overhaul, repair, inspection and storage and disposal process. Includes both direct and indirect expense-type materials. Excludes reparable components from rotatable pools (Cost Elements

308.1.1, 308.2.1, 308.3.1) and modification kits (Cost Elements 201.1.1 and 201.2.1).

304.2 Ships/Boats

304.2.1 Regular Ship Overhaul - The cost of the shipyard periods scheduled in advance for the accomplishment of major maintenance and repair in accordance with the requirements set forth in the Top Level Requirements (TLR) or other planning documents.

304.2.1.1 Manpower - The cost of the labor expended by the shipyard in support of ships serviced. The labor cost will be a fully-loaded cost to account for a pro rata share of direct, indirect, and overhead costs.

304.2.1.2 Material - The cost of the material and repair parts expended by the shipyard in support of ships serviced. Excludes replenishment spares (Cost Element 308.2.1) and modification kits (Cost Element 201.1.1.4 and 201.1.2.4).

304.2.2 Non-Scheduled Ship Repair (RA/TA) - The cost of the maintenance and repair, performed in shipyards or other industrial facilities, resulting from casualties, voyage damage, etc. These are repairs between scheduled overhauls that are beyond the capacity of the ship's force to accomplish.

304.2.2.1 Manpower - The cost of the labor expended by the shipyard, or other industrial facility, in support of

ships serviced. The labor cost will be a fully-loaded cost to account for a pro rata share of direct, indirect, and overhead costs.

304.2.2.2.2 Material - The cost of the materials and repair parts (expense items) expended by the shipyard, or other industrial facility, in support of ships serviced. Excludes replenishment spares (Cost Element 308.2.1).

304.2.3 Fleet Modernization Program (FMP) - The cost of the installation of alterations and improvements (i.e., SHIPALTS, ORDALTS, field changes, other modifications) to effect changes in a ship's configuration or equipment to improve its safety, habitability, maintainability, or technical characteristics. (Does not include GPS changes, modifications, alterations, or other improvements designed to enhance the performance or improve or alter the mission capability of the ship). These exclusions are investment in the system and therefore are to be included in System Investment, Cost Element 201.

304.2.3.1 Manpower - Labor cost will be a fully-loaded cost to account for a pro rata share of direct, indirect, and overhead costs.

3404.2.3.2 Material - Cost of miscellaneous industrial material such as wire, cabling, piping, fittings, sheet metal, locally procured or fabricated items provided by the installation activity. Costs for special program material

required only for these alterations and modifications are included in Cost Element 308.2.2.

304.2.4 Recording - Not applicable to GPS.

304.2.5 Selected Restricted Availability - The cost of shipyard periods scheduled in advance in accordance with the requirements set forth in the Top Level Requirement (TLR) or other planning documents for the accomplishment of maintenance.

304.2.5.1 Manpower - the cost of labor expended by the shipyard in support of ships serviced. The labor cost will be a fully-loaded cost to account for a pro rata share or direct, indirect, and overhead costs.

304.2.5.2 Material - The cost of the material and repair parts (expense items) expended by the shipyard in support of ships serviced. Excludes replenishment spares (Cost Elements 308.1.1, 308.2.1, and 308.3.1) and Special Program Material (Cost Element 308.2.2).

304.2.6 Repairable Component Repair - The cost of the repair, calibration, and testing of the ship's equipment and components at industrial facilities. Although most Navy GPS components will be overhauled/repaired at USAF installations, the AF industrial funds must be reimbursed by the Navy. Accordingly, depot repair costs for all Navy GPS components should be included in this cost element. Labor and material

costs are similar to those described in other cost elements above.

305 Depot Supply - The cost of manpower and material needed to procure, receive, issue, manage, and control the supplies, spares and repair parts (wholesale supply functions) used in operating and maintaining combat vehicles, aircraft, and ship/boats, and associated trainers/simulators, and support equipment; and to provide sustaining (service) engineering and technical data support as well as logistics information systems support. Includes contractual support. Does not include the cost of end items procured, stored, etc. (Cost Element 308); nor does it include the cost of distribution of these items (Cost Element 305). For GPS, these are Air Force costs, for the most part, although the Army and Navy may incur costs for service-unique SE, trainers, and GPS LRUs.

305.1 Aircraft and 305.3 Ground Units

Material Distribution (Cost Elements 305.1.1 and 305.3.1) - The cost of manpower and material needed to fill requisitions for supplies, spares, and repair parts and maintain control and accountability of these assets.

Material Management (Cost Elements 305.1.2 and 305.3.2) - The cost of manpower and material needed to manage the procurement of supplies, spares and repair parts and maintain

control and accountability of these assets. Includes contractor logistic support costs.

Technical Support (Cost Elements 305.1.3 and 305.3.3) - The cost of sustaining (service) engineering, technical data and documents needed to perform sustaining engineering and maintenance on aircraft and combat vehicles, associated components, trainers/simulators and support equipment.

305.2 Ships/Boats

305.2.1 General Support - The cost of supply and information functions that support the ships. Includes costs for operation of Inventory Control Points (ICPs), supply depots, other field support, technical documentation update, 3-M support, etc.

305.2.2 Engineering and Technical Services - The cost of engineering and technical support services other than those supplied by IMAs and depot maintenance activit.

306 Second Destination Transportation - The round-trip cost of transporting reparable secondary items to depot/contract maintenance/activities and back to the operational unit or CONUS stock points, and the one-way cost of transporting repair parts from CONUS stock points to depot and below depot maintenance activities. Excludes deliveries by the Mobile Logistic Support Force, since the GPS-relevant cost is not considered sufficiently significant to warrant specific treatment. Each service will fund for Second

Destination Transportation of its own GPS sets/components out of their operations and maintenance funds.

307 Personnel Support and Training - The variable cost of individual training (initial and replacement training, health care, permanent change of station (including household goods movement), and other personnel support.

Individual Training, Cost Elements 307.1.1, 307.2.1, 307.3.1 - The variable cost of recruit and technical training, including the pay allowance of training pipeline personnel and the cost of their instruction (including instructor pay and allowances). Excludes pay and allowances of trainees attached to a ship (Cost Element 301.1.2.2 (TAD)).

Factory training provided by contractors at their facilities to qualify an initial cadre of skilled personnel to: (1) operate and maintain a weapon system which operationally deployed, or (2) initially man the service's weapon systems-related training courses, is paid for by both investment and O&M funds. Contractor instructor pay and the cost of instruction at contractor facilities are categorized as investment costs - the pay and allowances of service military and civilian personnel attending the factory schools is an O&S cost. (See 202.2).

Health Care, Cost Elements 307.1.2, 307.2.2, and 307.3.2 - The variable cost of providing medical support to deployed

units, below depot maintenance, installation support and training piepline personnel; and including the pay of medical personnel who provide this support and medical material. In the Navy, this is the cost of providing ashore medical support to personnel attached to the ship, whereas, the cost for organization medical support is accounted for in 301.4.

Personnel Activities, Cost Elements 307.1.3, 307.2.3, and 307.3.3 - The PCS costs, including household goods movement, of deployed unit, below depot maintenance, installation, support, training pipeline, and medical personnel.

Personnel Support, Cost Elements 307.1.4, 307.2.4, and 307.3.4 - The cost of supplies, services and equipment needed to support training pipeline and medical personnel. Examples of costs are administrative supplies, travel expenses, expendable office equipment and machines, custodial services, and other variable personnel-oriented support costs incurred at training and medical facilities.

308 Sustaining Investment - The cost of procuring replenishment spares, support equipment special program material, training ordnance and certain modification kits and material.

Replenishing Spares, Cost Elements 308.1.1, 308.2.1, and 308.3.1 - The cost of recurring procurement of spares to replenish rotatable pools of repairable components depleted

through abandonment, loss, or survey or to increase existing stocks to meet unanticipated demand rates. Spares are recoverable components, sub-assemblies, assemblies, equipments, or end items installed, stored, or otherwise placed in use as replacements for items undergoing maintenance, repair, overhaul, salvage, or in the pipeline. The acquisition of initial spares is covered in Cost Element 202.4.

Modification Kits and Material, and Special Program Material, Cost elements 308.1.2, 308.2.2, and 308.3.2 - The purchase cost of modification kits (and spares) and material to modify aircraft, combat vehicles, and ships/boats (including SHIPALTS, ORDALTS), associated components, support equipment, and trainers/simulators to make them safe, habitable, more easily maintained, enable them to perform mission-essential tasks (not new capability), or reduce maintenance costs. Changes, modifications, or alterations to enhance mission capability, i.e., improve performance, are investment costs, Cost Element 201. GPS-related costs would be included here only after installation and subsequent operation revealed deficiencies in design, either of the GPS equipment or its integration.

Replenishment Support Equipment, Cost Elements 308.1.3, 308.2.3, and 308.3.3 - The cost of replenishing common servicing equipment, maintenance and repair shop equipment,

instruments and laboratory test equipment, and other equipment including spares of these requirements. Covers such items as auxiliary generators; engine stands; test sets for radios, radars and fire control systems; hand tools; compressors; guages and other minor items. These equipment demands are generated by a need to: (1) replace peculiar support equipment bought using procurement funds (2) obtain common off-the-shelf ground equipment needed to support operations as production combat vehicles arrive in the operating inventory; and (3) replenish common support equipment no longer usable.

Training Ordnance, Cost Elements 308.1.4, 308.2.4, and 308.3.4 - The cost of the expendable ordnance, ammunition, pyrotechnics, missiles, ballistic weapons, guided weapons, torpedoes, mines, depth charges, sonobuoys used in training exercises. There are no significant GPS-relevant costs for peacetime.

Munitions, Cost Elements 308.1.4.1, 308.2.4.1, and 308.3.4.1 - The cost of munitions (live and inert) expended by the operating unit for the purpose of sustaining aircrew proficiency in weapon delivery techniques.

Missiles, Cost Elements 308.1.4.2, 308.2.4.2, and 308.3.4.2 - The cost of missiles (live and inert) expended by the operating unit for the purpose of sustaining aircrew proficiency in weapon delivery techniques.

Sonobuoys, Cost Elements 308.1.4.3 and 308.2.4.3 - The cost of sonobuoys used during peacetime.

APPENDIX D

Program/Project Year Discount Factors

Table A[1]	Table B[2]
PRESENT VALUE OF $1 (Single Amount - To be used when cash-flows accrue in different amounts each year).	PRESENT VALUE OF $1 (Cumulative Uniform Series - To be used when cash-flows accrue in the same amount each year).

Project Year	10%	10%
1	0.954	0.954
2	0.867	1.821
3	0.788	2.609
4	0.717	3.326
5	0.652	3.977
6	0.592	4.570
7	0.538	5.108
8	0.489	5.597
9	0.445	6.042
10	0.405	6.447
11	0.368	6.815
12	0.334	7.149
13	0.304	7.003
14	0.276	7.729
15	0.251	7.980
16	0.228	8.209
17	0.208	8.416
18	0.189	8.605
19	0.172	8.777
20	0.156	8.933
21	0.142	9.074
22	0.129	9.203
23	0.117	9.320
24	0.107	9.427
25	0.097	9.324

1 Factors are based on continuous compounding of interest at the stated effective rate per annum, assuming uniform cash flows throughout stated one-year periods. These factors are equivalent to an arithmetic average of beginning and end of the year compound amount factors found in standard present value tables.

2 Table B factors represent the cumulative sum of the factors in Table A at the end of any given year.

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